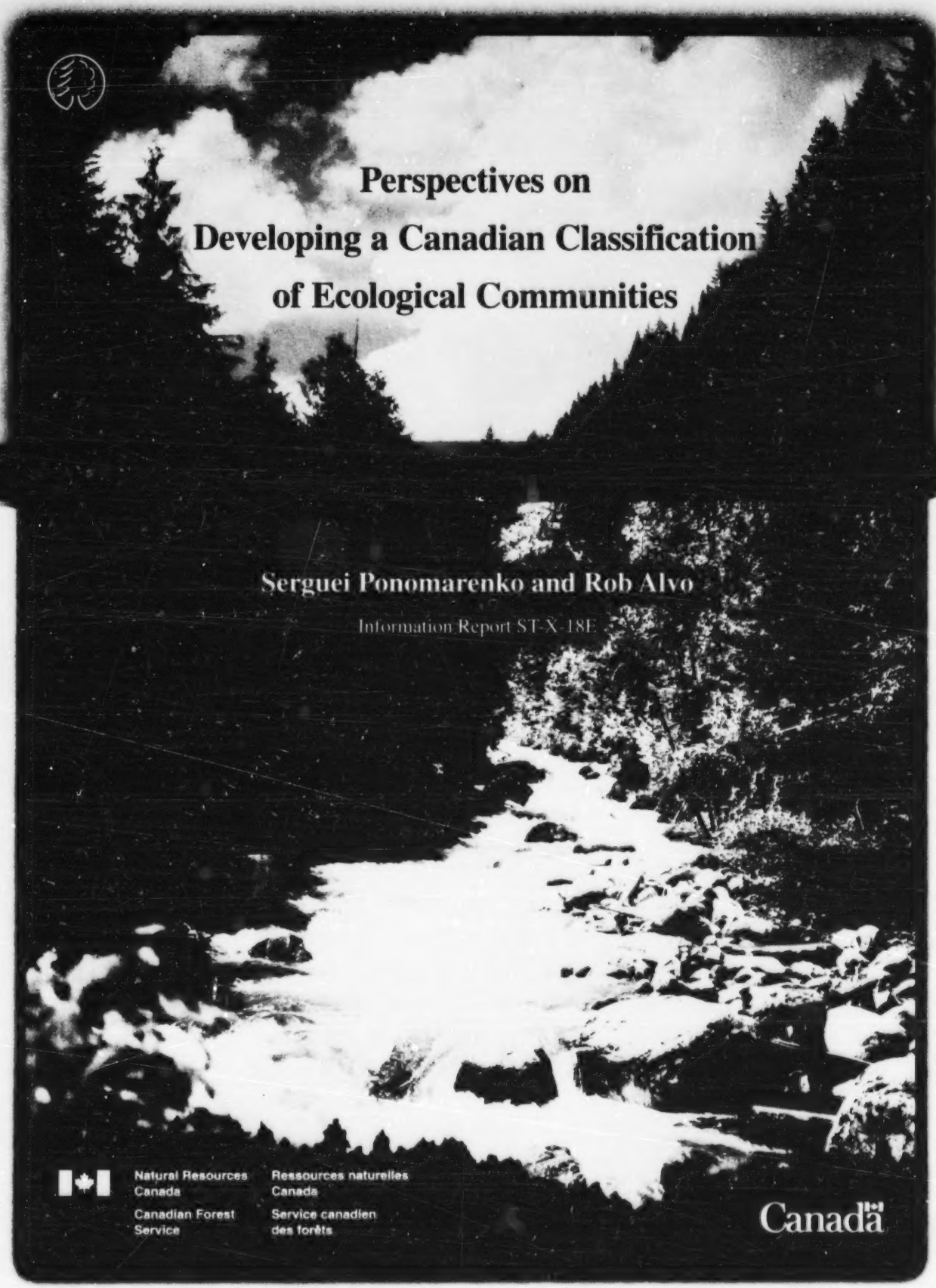

Perspectives on Developing a Canadian Classification of Ecological Communities

Serguei Ponomarenko and Rob Alvo

Information Report ST-X-18E

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Serguei Ponomarenko and Rob Alvo

Canadian Heritage, Parks Canada
Ecological Integrity Branch
Hull, Quebec

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Abstract

During the last few decades, biodiversity conservation and biodiversity management have become increasingly important at subnational, national, and international levels throughout the world. This has evoked a practical necessity for the development of national and international ecological community classifications. One can reasonably predict that eventually, and possibly very soon, a global ecological community classification will be developed as a collaborative effort of many countries and international organizations.

Currently there are two centers of fast-expanding international ecological community classifications. The first now embraces 25 European and Asian countries. The second is in North America, where the Association for Biodiversity Information, an international nongovernmental organization, is developing an International Classification of Ecological Communities (ICEC). Only the United States terrestrial portion of this classification (U.S.-National Vegetation Classification, or US-NVC) is well-developed, whereas freshwater, marine/ estuarine, and subterranean portions are under development. The ICEC is currently being applied in the United States, Canada, Mexico, and some Caribbean countries (Jamaica, Puerto Rico, and Cuba). It is beginning to be applied across some Latin American countries as well. Recently, the United States government adopted the US-NVC as the standard to be used across all federal agencies.

We believe that Canada also needs a national ecological community classification that would include all types of biotic communities (terrestrial, subterranean, freshwater, and marine). Having such a classification would allow Canada to be well represented in the development of a global conventional classification. The first step in developing a national ecological community classification should be a Canadian National Vegetation Classification (C-NVC). More than 50 existing local ecosystem classifications would be used as the starting point for the development of this national classification.

In sections 1–5 we present an overview of different classifications worldwide and in Canada. Section 6 contains our personal views concerning the development of a Canadian Classification of Ecological Communities and a Canadian National Vegetation Classification. We examine possible relationships between the proposed C-NVC and existing classifications in Canada. We conclude that the ICEC model for the classification of ecological communities should be used as a standard for developing the C-NVC. The ICEC is already broadly used in Canada, and development of the C-NVC following the same standards would help create a common classification at the continental scale.

Introduction

The last decade greatly changed the global attitude regarding nature conservation from a vaguely defined preservation of "wilderness" to include the concept of sustainable development. This concept has many aspects, but in relation to biodiversity it means that biodiversity conservation and biodiversity utilization are inextricably linked.

Biodiversity Conservation

In 1992, the Convention on Biological Diversity was signed at the global summit in Rio de Janeiro, Brazil. This event heralded a new period during which biodiversity conservation is not only

a moral obligation of those who accept it, but an international law posing certain responsibilities to each country. Indeed, biodiversity conservation was determined to be one of the overall challenges to humanity that must be dealt with globally, nationally, regionally, and locally (Convention on Biological Diversity 1992).

Biological diversity may be identified as consisting of three parts (Mosquin et al. 1995):

- Individual species diversity.
- Genetic diversity, generally referring to genetic variations within individual species.
- Ecosystem diversity, or diversity of species assemblages, which are adapted to living together.

However, preservation of ecosystem diversity does not constitute one third of needed biodiversity conservation efforts. Of the estimated 30–50 million species on earth, only 1.75 million have been named and classified (Wilson 1992). At present, most species cannot be monitored on an individual species basis, much less preserved. Thus, for preserving all three components of biological diversity, the ecosystem level is becoming a crucial chain. By preserving a sufficient number of different types of ecosystem, we can be sure that most species have a good chance to survive even before they are discovered. Preservation of ecosystems must be combined with individual conservation measures for selected species.

Biodiversity Utilization

Many spheres of our activity, such as hunting, forestry, agriculture, parts of medicine, and others, are directly connected with biodiversity utilization. Nevertheless, indirect influences on biodiversity, resulting in the alteration of natural communities, promoting some species and placing many others at risk of extinction, constitute a significant part of the problem. When we drive a car, for example, we consume biodiversity in many ways. Pumping the oil from the ground, oil spills, road construction—all these are very serious risk factors for components of biodiversity. In the last century, mainly indirect influences caused the extinction of biological species and this process continues at an accelerating rate. It became more and more evident that traditional conservation measures are not enough to preserve biodiversity. People have to change many aspects of their actions and undertake special measures to steward and restore biodiversity. Recently, restoration ecology has become a fast-growing business. This is why biodiversity stewardship probably describes more adequately our activities aimed at preserving biodiversity.

To fulfill the global task of preserving ecosystem diversity, people need some scientific and management tools, such as classifications for biodiversity at the ecosystem level. Ecosystem classifications provide:

- A common language to name ecosystems uniformly.
- A tool to analyze and access the state of ecosystems and monitor their trends. This is a very important activity for various spheres of decision making.
- A tool for ecosystem managers to develop ecosystem management techniques, which can be generalized from one example to the whole class of ecosystems.

To date, most ecosystem classifications have been developed as a scientific exercise and have been applied mainly in science, although they may have had a broader application.

Today, biodiversity stewardship has become more and more a regular business for governments at different levels to reflect their responsibilities according to international and domestic laws. This significant change requires standard classifications to allow the efforts of different territorial entities to be prioritized and compared. One of the latest initiatives of the International Union of Conservation of Nature (IUCN) Commission on Ecosystem Management, "A global framework for assessing the status of ecosystems, and facilitating their integrated management," 1998, proposes to "provide scientifically rigorous and objective tools for (i) assessing and monitoring of the status of ecosystems, and (ii) planning and management using an ecosystem approach." However, there is no mention of which ecosystem classification(s) would be used or whether one would have to be developed.

At present, Canada does not have a standard ecosystem classification that is applicable at a detailed natural community level as well as to a broader countrywide level.

Objectives

The four objectives of this report are:

- to propose an approach for developing a Canadian Classification of Ecological Communities (CCEC) that would be applicable to a broad range of biodiversity issues;
- to present different classification approaches in order to propose an approach to develop a standard Canadian National Vegetation Classification (C-NVC), which would be the first portion of the CCEC;
- to determine how existing Canadian classifications could relate to this proposed standard C-NVC;
- to analyze current Canadian regional forest ecosystem classifications to propose a method for developing a Canadian forest ecosystem classification completely compatible with the C-NVC.

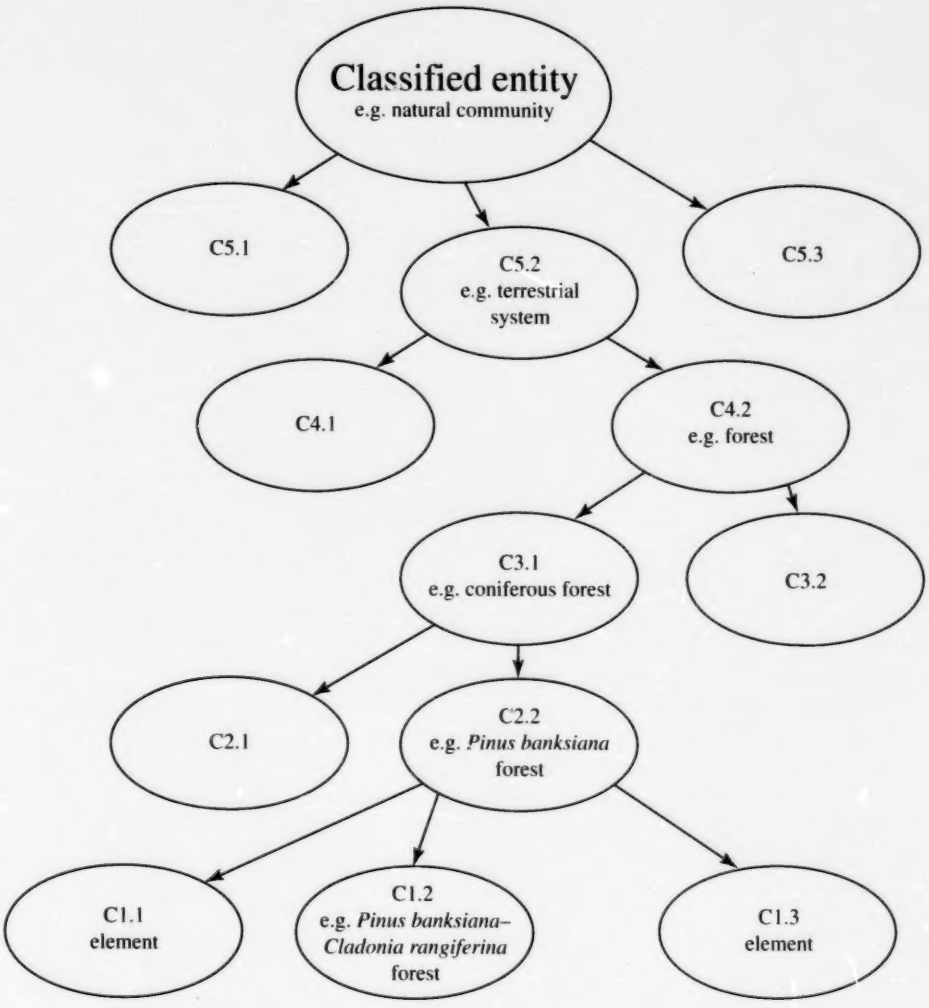

Figure 1. A hierarchical element-based classification. Cx.x, class at any level; C1.x, element, or class at the lowest level; \, unambiguous criterion.

1. Background on Classification Science

Classification is a method of arranging in a comprehensible order the totality of elements or varieties of phenomena. Its main functions are to sort and group classified elements (Hempel 1964).

One of the current problems in classification science is the ambiguous interpretation of many terms. We therefore define some terms here. Following Dunnel (1994), we can consider classification "as a special kind of a larger, more inclusive phenomenon which, for lack of a better term, can be called arrangement":

"Arrangement can be taken to encompass any activity which has as its product an order or orders, any procedure which leads to unitizing."

In this publication we will discuss several types of arrangements: classical classifications, divisions, and ordinations.

1.1 Classical or Element-based Classifications

Classification "will be restricted to arrangement in the ideational realm and defined as the creation of units of meaning by stipulating redundancies (classes)" (Dunnel 1994).

A classical classification has the following features:

1. Each classification presumes the existence of elements, to which it can be applied.
2. Each classification has a scheme consisting of classes. In the case of hierarchical classification, classes are arranged into hierarchical levels.
3. Each classification has criteria for distinguishing among classes.
4. Each classification presumes a procedure of assigning an object of classification, or an element, to a certain class

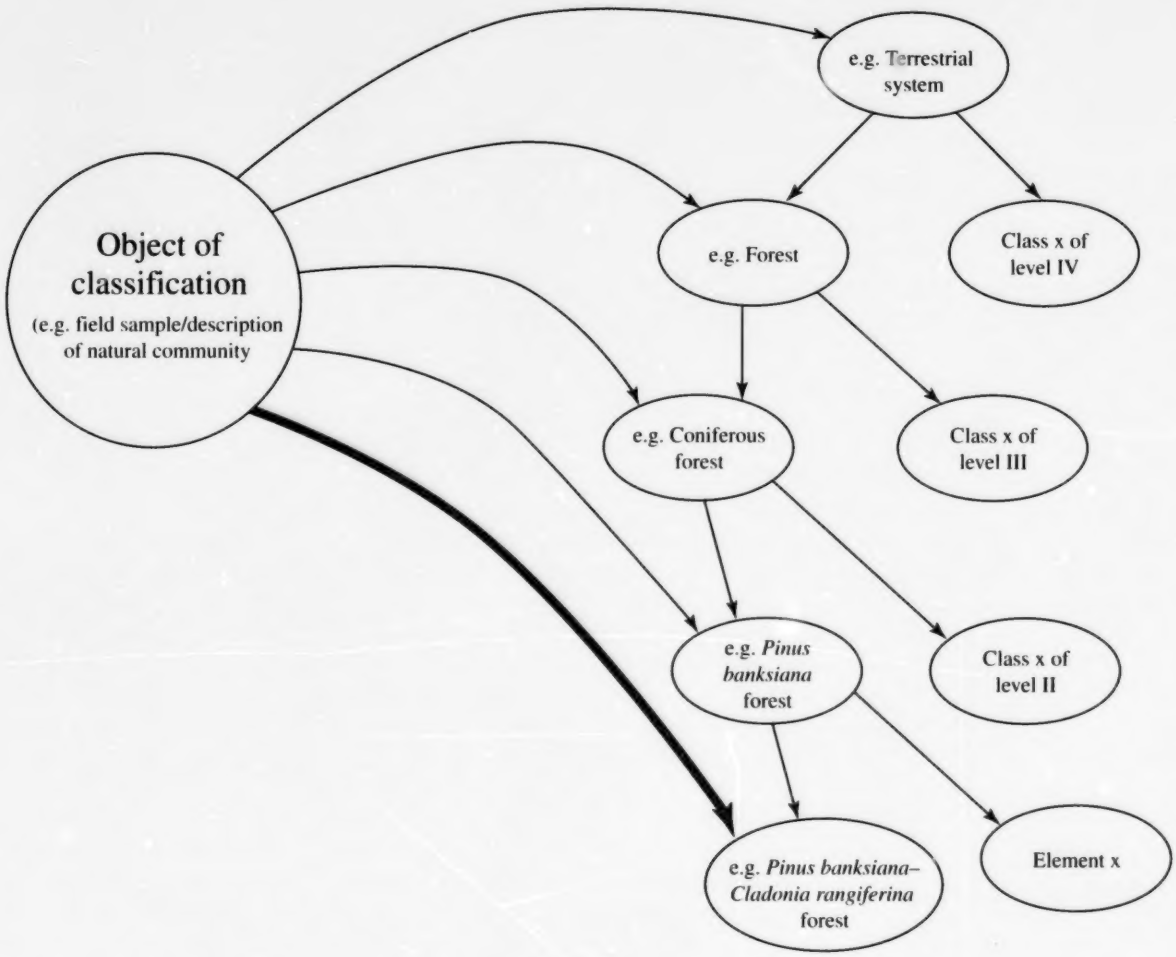

Figure 2. Classification procedure: an object of classification is assigned to the appropriate class at each level and is identified as an element.

using the criteria. In some cases, application of criteria needs an arbitrary decision but it does not deny application of them.

The term "classification" has a double meaning. The first meaning of "a classification" applies to features 2 and 3. "A classification" is a structure consisting of classes and criteria for distinguishing them.

The second meaning of "classification" is a process of assigning objects of classification to a certain class.

Figures 1 and 2 illustrate these two meanings of a classical classification. Figure 1 represents a classification as a structure (corresponds to features 1, 2, and 3). Figure 2 shows a process of classification (corresponds to feature 4). Synonyms of the term "classification" are taxonomy (this term is used for classification of biological species) and typology (this term is sometimes used in natural sciences). As a synonym of classical classification, we will use the term "element-based classification", which points to the existence of elements in these classifications.

1.1.1 Objects of classification, elements, and classes

These three terms are very important in classification science and need to be defined. Whereas the object of classification is an object of a real world (the object, this particular one), class is a generic name in classification science reflecting some essential features of this object according to criteria of this class identification. Class is an idea separated from other ideas by these criteria. It refers to units of classification on all hierarchical levels. Elements, or elementary units, are classes of the lowest hierarchical level in a classification. For example, "the house" is an object of a real world having countless parameters, but not all of them are essential for identifying it as "a house". In the classification of houses there could be several hierarchical levels and classes

corresponding to them, but one cannot go below the level of "a house". A house is a class of lowest level. It is an element of this classification. Likewise, species are elements of Linnaeus's classification, while a particular plant growing in a pot is an object of classification. In the case of the Braun-Blanquet (1921) vegetation classification, the associations *Rhodobryo–Piceetum asperuletosum* or *Agropyretum* are examples of elements, or classes on the lowest level, but particular stands of these associations are objects of classification.

Coincidentally, the same term "class" is sometimes used in a narrower meaning for only a certain hierarchical level as it is in the species classification.

1.2 Divisions

Similar to classification is another type of arrangement, namely division. Division is an arrangement in which a spatial entity is divided into parts by applying certain criteria. Division presumes no classes and, consequently, no scheme of them. A political map of the world is an example of a division. Countries are parts of the earth's surface. On lower hierarchical levels, subdivision goes to province and county levels. None is a class—each one is itself. But one can classify countries into three classes: "first world", "second world", and "third world" countries. In this case, countries represent objects of classification; a classification scheme consists of three classes at one level and there are some criteria to distinguish among these classes. Using additional criteria we could classify each of these classes into classes of a lower hierarchical level. Another example of a division follows: we have several apples representing a mixture of different sorts lying randomly on the ground. We can spatially split all of them into several groups by predominant color of apples in a certain area (green, pink, or yellow). In each area we will have apples of different sorts but not in an equal proportion. We have applied a certain criterion for dividing the area covered by apples but we have not classified apples in a strict meaning of this term. However, the term "classifying", or "classification process", is used for a similar procedure in cartography. To avoid logical misinterpretation, we will use the term "classification" only in its classical meaning, excluding the meaning of division from it. For describing "classification process" in cartography, we will use the term "interpretation" in this paper, although a better term could probably be found.[1] Thus, classifications and divisions are two main procedures that are used to arrange a heterogenic entity. But in the first case, this arrangement is based on the revealing of recurrent elements and in the second one, the arrangement is based on delineation of similar patterns of heterogeneity without identification of its elements.

Divisions as well as classifications have several meanings:

- Division as a process of division.
- Division as a result of division (structure).
- Division as a unit of division.

Division is of a heterogenic mixture arrangement. In the case of mapping, "regionalization" (Isachenko 1970) is a synonym of division. Thus regionalization is a kind of division used in mapping. In the text that follows, we will also use the term "regionalization type of classification" because many regionalization systems are called classifications. Parts of a land division (regionalization) are land units. A land unit is any delineated area at any hierarchical level in a land division.

To interpret or "classify" delineated land units, a researcher must develop a set of gradations for each feature in question. Each of these gradations may or may not represent a formal element-based classification. For example, a researcher wants to regionalize the landscape using the three most important features of the given area: soil thickness, vegetation, and soil salinity. For soil thickness a researcher can use three grades: (1) deep soil (more than 50 cm), (2) shallow soil (10–50 cm), and (3) rock (less than 10 cm of soil). For vegetation there can also be three grades: (A) forest, (B) shrub, and (C) grassland. The third feature also has three grades: (a) very saline (more than 3 g/kg), (b) saline (0.5–3 g/kg), and (c) nonsaline (less than 0.5 g/kg). The correlation among these features can be tight or loose. Based on these three scales for the three features, the researcher can delineate a significant land area into land units possessing predominantly a certain combination of these features. The result of this procedure will be a landscape map for the given area reflecting landscape regions. In this example, we can see that the researcher did not use any formal element-based classifications for gradation of soil, vegetation, and salinity; or the researcher developed his own three simplest element-based classifications each consisting of three classes.

In another example, a researcher may use some existing well-developed element-based classifications for scaling the features, such as the Canadian System of Soil Classification (Canada Soil Survey Committee 1978).

In both these examples, a researcher produced scientifically valid maps, but in the second example, his regionalization is compatible with the Canadian System of Soil Classification and this circumstance enhances the potential application of this mapping product.

Figure 3 illustrates a procedure of division in a more formal way. An area is divided into three distinctive regions (spatial units). Three features are used for the division: I, II, and III. Each feature has several grades. An element-based classification is developed only for feature I. In spatial unit no. 1, predominant elements are 1, B, and a, though there are some other elements in small proportions.

[1] Krajina (1969) used the term "stratification". He wrote: "It is necessary to study such different habitats, classified by the biogeocoenoses (Sukachev 1944) or plant associations (Braun-Blanquet 1921) and stratified by geographically distinct biogeoclimatic zonal units (Krajina 1965)."

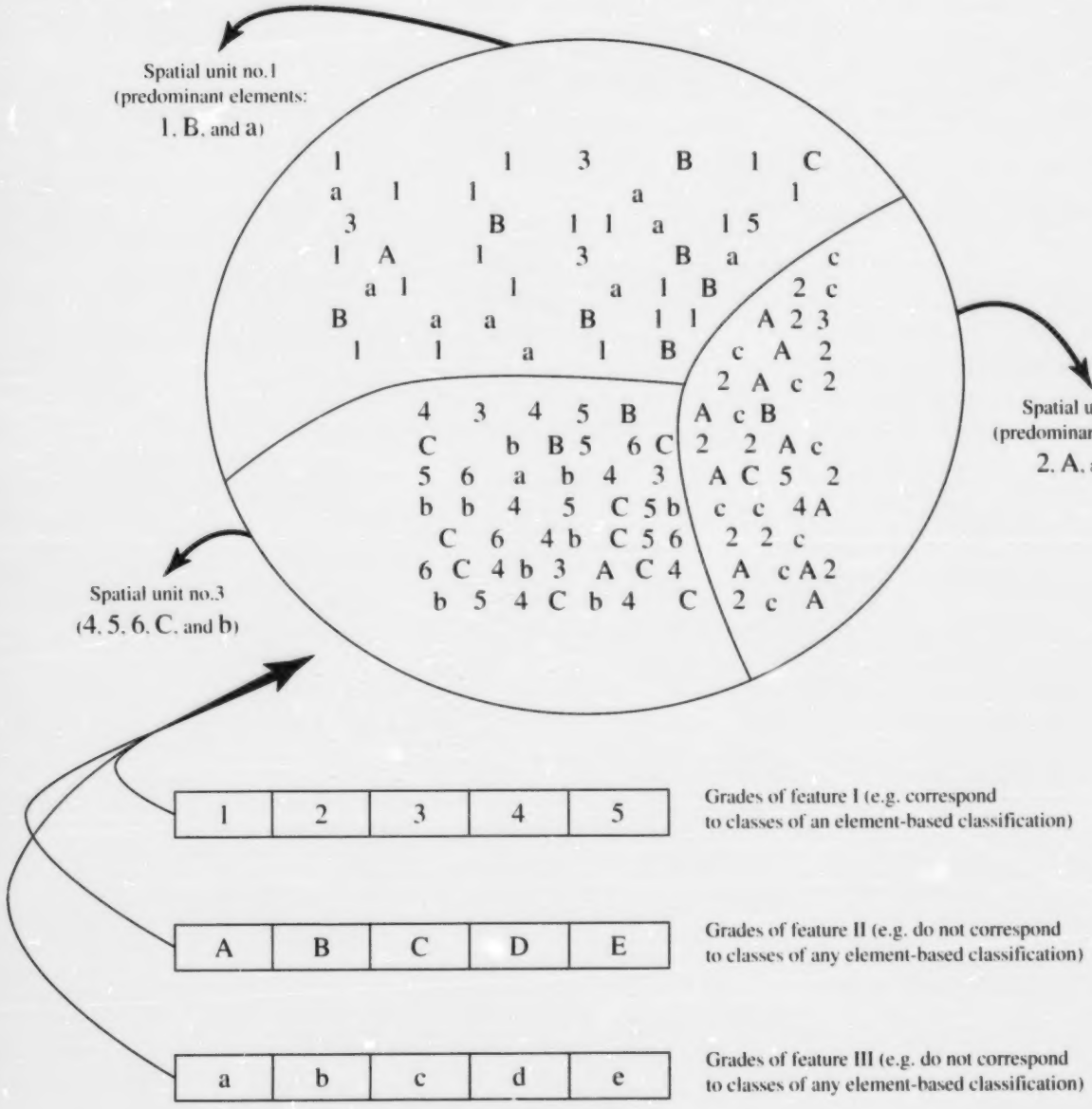
Spatial unit no.1
(predominant elements:
1, B, and a)
Spatial unit no.2
(predominant elements:
2, A, and c)
Spatial unit no.3
(4, 5, 6, C, and b)
1 2 3 4 5
Grades of feature I (e.g. correspond to classes of an element-based classification)
A B C D E
Grades of feature II (e.g. do not correspond to classes of any element-based classification)
a b c d e
Grades of feature III (e.g. do not correspond to classes of any element-based classification)

Figure 3. Division, or regionalization, procedure.

The relationship between regionalization and element-based classifications is also discussed in section 6.5.

1.3 Distinction Between Classifications and Divisions

Classifications and divisions have similarities and differences in the way they are developed and applied. Most land classifications fall into categories of classification or division. Some of them combine these two arrangements. This produces some ambiguity in understanding the term classification, and in the case of different land classifications analysis, it may lead to some confusion. Therefore, in the following analysis we will clarify whether we are dealing with a classification or a division.

Practically, it is easy to distinguish between an ecosystem classification and an ecosystem division by the following procedure. If for any given plot of land one can identify the classifi-

cation unit of lowest level to which it belongs using only field characteristics of the plot, one is dealing with a classification. However, if to identify a classification unit to which this plot is affiliated, one must have the coordinates of the plot and a map showing the delineation of classification units, then one is dealing with a division.

1.4 Ordinations

Ordination is a type of arrangement in which objects are placed along a gradient axis according to some of their parameters or features.

1.5 Element-based Classifications, Mapping, and Legends

Classification and mapping are two related but independent procedures. The development of an element-based classification is a first step that results in a list of classes for any given hierarchical level, their description and criteria for their identification. Mapping is just one of many possible applications of an element-based classification. One classification can be used as a reference source for numerous mapping projects. In this case, a certain hierarchical level of the classification can be used for developing a particular map legend. A map legend is not an equivalent of the corresponding classification.

The following are differences between a map legend and a corresponding classification:

- A legend usually uses only one hierarchical level of the classification, whereas the classification can have several of them.
- A legend does not need to include all classes of a certain level, but only those that can be mapped with a given scale on the given area in a particular mapping project. A classification includes classes at all levels. Furthermore, certain classes can be merged in a legend's element since, for example, mapping methods do not allow for distinctions among merged classes.
- A legend does not need to have an exhaustive identification of its elements, whereas a classification has strict criteria to distinguish among classes.
- A legend does not have to be based on one logical scheme, whereas a classification does. For example, a legend may include pine forest, spruce forest, and residential areas and roads. In this example, the legend's elements are not parts of a single classification.
- Finally, a legend may or may not be based on a classification. In many past and present situations, biotic community mapping projects are not based on any element-based classification. Issues of how to map classification elements or other classes do not constitute a part of a classification itself and they must be solved in mapping projects. Other issues of the relation between classification and mapping are discussed by Grossman et al. (1998).

2. Terminology in Ecology

"The present confusion in the terminology of vegetation units is a fact well known to all ecologists."
G. Einar Du Rietz (1930)

2.1 Units of Classification

What is the basic unit in ecosystem classification? The term "ecosystem" (Tansley 1935) is accepted throughout the world. The broad meaning of this term is any natural system where biotic and abiotic components interact with each other. Examples of these could range from a drop of water with bacteria living in it to the global ecosystem. The meaning of this term has a deep gnoseological importance, but in practical scientific analysis one often needs to be more precise about the size of the system in question. For classification purposes we need to identify the smallest feasible size of ecosystem that can be used as its elementary unit to be classified. The search for such a term began in the nineteenth century.

In 1910, The Third International Botanical Congress proposed the term "association" as an elementary unit of vegetation cover that can be classified and mapped. As was stated at the congress "an association is a plant community of definite floristic composition, uniform habitat condition and uniform physiognomy" (Flahault and Schröter 1910). Braun-Blanquet narrowed the definition of association to floristic composition only: "a plant community characterized by definite floristic and sociological (organizational) features which show, by the presence of character-species (exclusive, selective and preferential), a certain independence" (Braun-Blanquet 1921 in Grossman et al. 1998). This term, however, encompasses only vegetation, which is only part of an ecosystem. A more generic term was needed corresponding to association in size and concept but including all biological and abiotic components.

The term "biogeocoenose" proposed by Sukachev (1944) was intended to fill this gap. In the Russian ecological literature, the term "biogeocoenose" is widely used as a synonym of ecosystem on the spatial level of vegetation association. A science studying biogeocoenoses correspondingly has the name biogeocoenology. In Canada, for practical purposes of ecosystem classification, Krajina (1960) proposed this term. Pojar et al. (1987) and Meidinger and Pojar (1991) use this term as an ecosystem elementary classification unit in the biogeoclimatic ecosystem classification. Biogeocoenose is a system corresponding to a homogeneous part of the land surface having a uniform biotic component (vegetation, fauna,

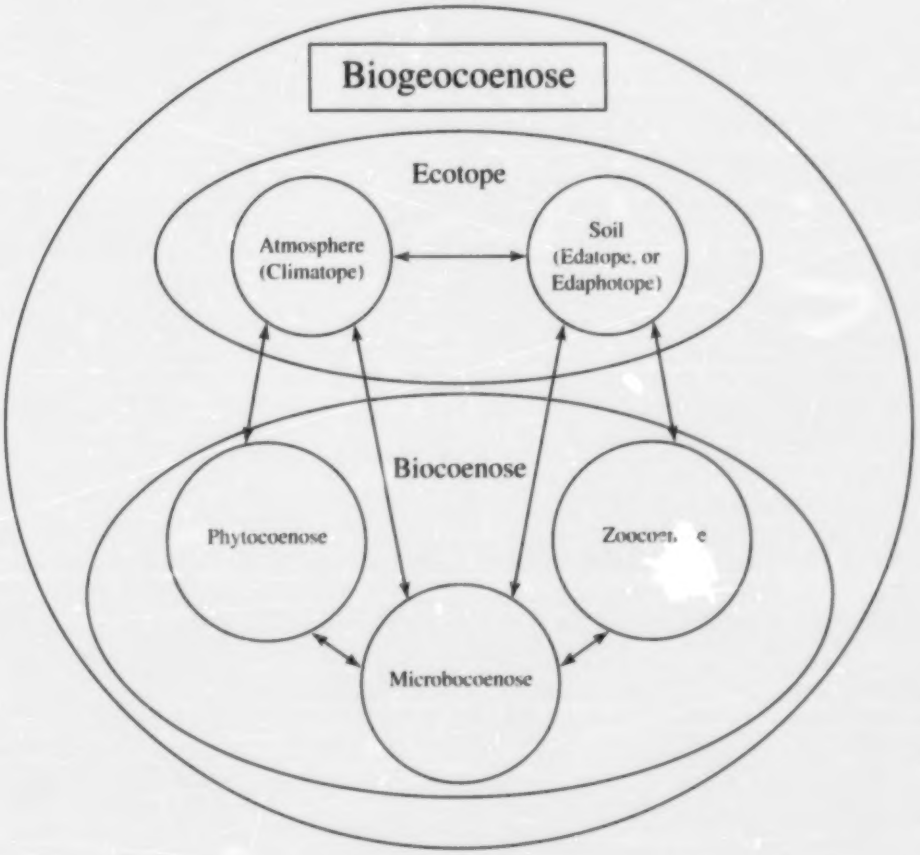

Figure 4. Components of biogeocoenose (Sukachev 1960).

and other), a uniform abiotic component (climate, soil, hydrology, parent material), and a uniform way in which they interact. A general scheme of biogeocoenose is presented in Figure 4. Biogeocoenose consists of biocoenose and ecotope. The biotic part of biogeocoenose is biocoenose. The abiotic part of it is ecotope and it consists of edatope, or ecosystem substrate conditions, and climatope, or ecosystem microclimate conditions. The vegetation part of the biocoenose is phytocoenose. The term "phytocoenose" is a synonym of "vegetation association". The term "biogeocoenose" was proposed originally only for terrestrial ecosystems, but it was later widened to be applicable to other ecosystems. The relationship between the terms "ecosystem" and "biogeocoenose" was originally discussed by Sukachev (1960). More recently the term "ecological community" has become popular. It is probably the closest analog to" biogeocoenose". We will use the terms "ecological community" and "biogeocoenose" as synonyms.

In the English literature, the term "natural community" is usually used as a synonym of the biotic part of an ecosystem at the spatial level of vegetation association (Whittaker 1962). Another common use of this term includes not only a biotic component, but an abiotic one as well. In this paper we will use this term in its first meaning. A synonym of the first meaning of "natural community" is "biotic community", a term recently promoted by Brown et al. (1998). Its use is much more consistent than that of "natural community". In this paper we will use the terms natural community, biotic community, and biocoenose as synonyms, although preference will be given to "biotic community" and "biocoenose" due to their consistent meaning.

The totality of animal species inhabiting a natural community (analog of plant association) has no special term in the English literature. In the Russian literature, however, it is called "zoocoenose". Furthermore, in the Russian literature, generic terms are used to specify the totality of certain phylogenetic groups of species affiliated with a certain natural community, such as "fungicoenose", "arthropodocoenose", etc. These terms are useful for classification purposes. In the same way that "biotic community"

corresponds to "biocoenose", a whole set of other terms using "community" instead of "coenose" (they are in fact synonyms) can be proposed: fungi community, arthropod community, etc.

In landscape science, the terms "biogeosystem" or "geobiosystem" are used as synonyms of "ecosystem", but the meaning of all three terms is not the same as it is in ecology (biogeocoenology). They emphasize abiotic processes more and biotic processes less compared to "ecosystem" in ecology (biogeocoenology) (see also section 3.2).

In phytosociology, along with the term "association", the terms "formation" and "dominance-type" are used to discern vegetation communities. The main distinction between these terms is how we identify vegetation communities.

Formations are identified by physiognomy only without any details about floristic composition. Dominance-type has two meanings used by different authors, in which it is identified by (1) dominant species in each stratum and (2) dominant species in the uppermost stratum. Associations are identified by floristic composition. We will use the term "dominance-type" in its first meaning. This term was proposed by Whittaker (1962), whereas other authors, for example, Sukachev and Du Reitz, use the term "association" in both situations. In some situations these three terms (association, dominance-type, and formation) can belong to the same classification, where associations are united into dominance-types and dominance-types are united in formations.

The term "forest cover type" is used mainly in forestry and reflects dominant tree species in the uppermost stratum (dominance calculated by tree basal area).

The term "forest type" has two meanings. The first meaning is equivalent to "vegetation type" and "plant community type" in forests. All three terms can be used to name plant community types regardless of how we identify them. The second meaning of "forest type" does not refer to existing vegetation but rather unites all sites appropriate for a certain potential vegetation type. Thus in its second meaning "forest type" is a unit of site or a unit of potential vegetation embracing a certain range of sites. In this second meaning it is used in Russia's forest ecological classification (see section 4.7.1) and in Newfoundland's forest ecological classification (see section 5.10.8). In other classifications the same idea is referred to differently: (1) "Site"—in Pogrebnyak's classification (see section 4.4) and in biogeoclimatic classification (see section 5.10.1.1, Site Classification); (2) "Ecological type"—in Land Classification System of the Ministère des Ressources naturelles du Québec (see section 5.10.6.1).

The definition of the term "site" varies a great deal including or excluding a current biotic component. We define it as a range of abiotic conditions appropriate for a certain type of late successional vegetation (Pogrebnyak 1929). Two main components identifying a site are edatope conditions and climate conditions (including microclimate). It indirectly includes relief as redistributor of edatope and (micro)climate conditions. One site is appropriate for a variety of biotic communities depending on the history of disturbances and successional stage.

Habitat is a grouping of ecosystems (biogeocoenoses) appropriate for a certain function (feeding, breeding, etc.) or for a complete life cycle of a biological species or a group of species. The term "habitat" reflects an idea of dependence of a given species on a given group of ecosystems (biogeocoenoses).

2.2 Terms for Classes and Objects of Classification

In common language and often in the scientific literature, the same term is used for classes, which represent ideas, and for objects of classification, which represent physical objects. In common language this is acceptable, but for classification application these two groups of terms must be strictly distinguished to avoid logical misinterpretation.

In the literature, the term "land unit" is used with two meanings: (1) a particular physical surface area, and (2) a land unit type. We will use it with the first meaning only. For the second meaning we propose to use the term "land unit class", or "land unit type"; for example, a bog polygon on a map is a land unit, but a bog as an element of a classification is a land unit type. The unspecified term "unit", of course, can be applied for division elements (land units, that is, delineated plots on a map) and for classification elements (land unit types).

The same problem exists with the use of the term "mapping unit". We propose to distinguish between mapping units and mappable units. A mapping unit is a physical polygon on a map. It corresponds to a land unit. A mappable unit exists without being mapped and reflects the potential to be mapped. It corresponds to a land unit class. A vegetation association is a mappable unit but not a mapping unit.

To distinguish between element-based classifications and regionalization type classifications, proper use of these two sets of terms is important. Units of element-based classifications are ideas, or concepts, that is, land unit types, mappable units, ecological unit types, etc. Units of regionalization type classifications are physical land areas or their representation on a map, that is, land units, mapping units, ecological units, etc.

3. Groups and Principles of Different Ecosystem Classifications

Because our main objective is to classify biodiversity at the ecosystem level, that is, the biotic components of ecosystems (see Figure 4), in the following text we will concentrate predominantly on classifications that focus on biotic components, although some of them include some abiotic ecosystem parameters as well.

In our analysis we will discuss only terrestrial classification approaches, not because aquatic ecosystem classifications have

not been developed or are not important, but because these two topics are rather independent due to the different structure of natural communities. Another consideration is tactical. We believe that the construction of a national classification should start from its terrestrial portion because it is better understood, whereas aquatic ecosystems are less well understood. Nevertheless, an overview and discussion on aquatic natural community classifications is a very important next step.

3.1 Classification of Classifications

Hundreds of ecosystem classifications were developed over the last century, and many were developed even earlier. To introduce some order we need to classify them. We can classify them according to application level (global, regional, and local), basic scientific concept (landscape science or ecology/biogeocoenology), classification approach (classical classifications or regionalizations), and other features.

3.2 Two Main Scientific Traditions for Classifying Ecosystems

Throughout the world two major scientific traditions have been developed to research and classify ecosystems.

The first tradition is "landscapeology", or landscape science. It develops geographical approaches to study ecosystems, or landscapes, or geobiosystems. The concept of landscape is the most integral view of land surface systems. Landscape here is viewed as a spatially hierarchical system. Functions of landscapes, or geobiosystems, are broader than those traditionally regarded as ecosystem functions in ecology. It is not only the interaction between biotic and abiotic components, but also geological, meteorological, geochemical, hydrological, and other processes. Thus, according to the landscape science school, geobiosystem is a more generic term than ecosystem. The biotic component in this tradition is considered at a very general level, which is not sufficient to classify biodiversity.

The second tradition is "ecology" or "biogeocoenology" and it has developed from the biological sciences. It focuses less on abiotic properties of biogeosystems and more on species composition and biological processes.

Both classifications and divisions are developed in landscape science and ecology, but their relative importance as scientific tools is different in these sciences. Divisions are more highly developed in landscape science whereas classifications are more highly developed in ecology.

3.3 Classifications

Units of ecosystem classifications are natural communities, biogeocoenoses, biocoenoses, phytocoenoses, vegetation associations, sites, edatopes, ecotopes, habitats, potential habitats, and elementary landscapes. Ecosystems can be classified according to their biotic and abiotic components or their combinations.

Among the abiotic components of natural communities, climate, landform, soil, surface geology, and hydrology are used for classifying ecosystems. Many abiotic parameters are manifested by vegetation, and very often abiotic component units are discerned by vegetation heterogeneity. However, abiotic components reflect biological assemblages of ecosystems only very generally and therefore cannot be used for the representation of biotic components.

3.4 Divisions

The main purpose of any land division is to delineate areas that are more homogenous in some way compared with other areas using some diagnostic features (see Figure 3 and explanation in section 1.2). The lower one moves in a hierarchical level of a division, the more homogenous is the area. Diagnostic features that are used at different levels can belong to different parameters of ecosystems, such as climate as expressed by vegetation, geomorphology, soil, underlying geology, and vegetation. Division does not require elements and classes (see section 1.2).

3.5 Why Choose Vegetation to Classify Terrestrial Natural Communities?

Among biotic components one can use any group of living organisms or their combination (vascular plants, invertebrates, vertebrates, fungi, lichens, protozoa, etc.), but for classification purposes vascular plants are usually used for terrestrial ecosystem classifications. There are several reasons for this: vascular plant communities (1) play a leading role in the energy budget of natural communities and represent in most cases the first level of the food chain; thus all other groups of organisms depend on plant communities; (2) are easy to recognize in the field and it is relatively easy to record species composition; (3) reflect to a degree the abiotic components of an ecosystem such as climate, soil, and hydrological regime; and (4) have many features that allow one to reconstruct past successions, shifts, and disturbances, and to predict future development of the natural communities under different conceivable conditions.

Therefore for the practical purpose of classifying biodiversity at the ecosystem level, we believe that the vegetation component must be taken as a leading component of terrestrial ecosystems for their classification.

Vegetation classification can be viewed as the most generic, integral, and standard habitat classification that can provide a framework for habitat classifications of separate species or groups of species (Tupikova and Komarova 1980; Levin 1981; Noss 1990; Franklin 1993; Grossman et al. 1998).

In any future development, vegetation will remain the backbone of natural community classifications. In some cases, however,

which do not belong to terrestrial natural communities, vegetation does not play a leading role in natural communities and may not even exist at all. Examples include cave, abyssal, and ocean bottom natural communities, and chemosynthetic communities in geological deposits and in areas of geochemical barriers.

3.6 Existing Vegetation Versus Potential Vegetation

Some vegetation communities are subject to quick changes, while others do not change significantly over extended periods of time. After some disturbances, vegetation community successions can recurrently lead to a more or less stable community. There are several classifications that intend to exclude temporary fluctuations and classify only stable communities. This is an important scientific task, but it is based on certain scientific speculations that can change from time to time. Also, the resolution level is much lower. We believe that for practical biodiversity and resource conservation and management, existing vegetation should be classified first.

4. Groups of Vegetation Community Classifications

As discussed previously (section 3.5), we will present an overview of classifications using vegetation as a leading, or at least a major, component. We will concentrate on element-based classifications developed in the ecology/biogeocoenology scientific tradition. We will not deal with potential vegetation classifications. Thus we have narrowed our field of research and can now concentrate on classification approaches of the chosen sector. Element-based vegetation community classifications fall into the groups discussed below according to the criteria for discerning ecosystem classes. Short analyses of different groups of vegetation classifications are given by Whittaker (1973a), National Vegetation Working Group (1990), and Grossman et al. (1998). Our goal is not to examine all significant classification systems developed thus far, but rather to give some examples of classification groups that could be helpful in discussing the present Canadian situation. Some of the classifications that follow are not strictly vegetation classifications, but rather site classifications; they are included for consistency with the later discussion concerning Canadian forest ecosystem classifications. In this section, we will discuss mainly classifications outside Canada. The Canadian classifications will be discussed in the next section.

4.1 Physiognomic Classifications

This is the oldest and most common type of ecosystem classification. In many cases it uses local terms from folklore, reflecting the fact that preclassifications of this sort were widely in use in the prescientific era.

Physiognomic units have distinctive macromorphological features (bog, cliff, takyr, etc.) that can be easily distinguished by a nonspecialist. Macromorphological features can include distinctive structures of vegetation communities, predominant growth forms of vegetation, and combinations of these with land forms and hydrological features. Physiognomic features can include major groupings of leaves (leaves versus needles), seasonality (evergreen versus deciduous), and others. Physiognomic units can usually be easily interpreted on aerial and satellite photos.

One of the first physiognomic classifications was developed by the famous geographer and traveler A. von Humboldt (1807), and now there are numerous regional and local physiognomic vegetation classifications. In boreal and temperate climate areas throughout the world, for example, most of Canada, the interest in physiognomic classifications at the regional and local levels significantly decreased due to their lower resolution compared to floristic systems. Nevertheless, in the tropics this approach is still quite popular. While becoming less popular at regional and local levels, physiognomic classifications preserve dominant positions at the macroregional and global levels. Several examples of global physiognomic classifications that use vegetation as a leading factor follow:

- Rubel (1930) classifications
- Schimper and Faber (1935) classifications
- Holdridge (1947, 1967) world physiognomy–climate relation classification
- Fosberg (1961) classification
- Ellenberg and Mueller-Domboir (1967) classification
- Walter (1968) world vegetation map
- UNESCO (1973) global vegetation classification.

4.1.1 UNESCO world classification

This classification is the result of international teamwork over several years. The team consisted of prominent scientists from Belgium, Germany, France, the United States, and Russia, who reviewed existing world classifications and concluded that none of them was entirely appropriate to serve as an international vegetation classification. In most cases, the UNESCO classification is based on climax vegetation, but in some cases climax interpretation of vegetation is not feasible and it reflects predominant natural vegetation.

The classification consists of five hierarchical levels:

Formation class. All possible types of vegetation are divided into five formation classes on the basis of growth form of the uppermost stratum and its structure (closed forest, woodland, scrub, dwarf scrub and related communities, and herbaceous vegetation).

Formation subclass. Each of the formation classes is divided into three to five subclasses mainly according to some characteristics of growth form, for example, leaf phenology.

Formation group is based on leaf type corresponding to climate.

Formation. A set of physiognomic features that identifies the main physiognomic types, which embrace floristically and geographically very different vegetation.

Subformation. This level divides formations according to some additional physiognomic features or by external environmental factors providing certain disturbance regime, for example, flooding.

The UNESCO classification was used to map the world vegetation at the 1:1 000 000 scale.

4.2 Floristic Approach

This approach differentiates plant communities on the basis of their total floristic composition. There are several modifications of this approach. The most elaborate of them was developed by Braun-Blanquet (1921), who founded the Zürich-Montpellier School of Phytosociology. Others represent some modification of the Braun-Blanquet system.

4.2.1 Braun-Blanquet, or Zürich–Montpellier approach to classification

Probably no other single person contributed as much to the development of natural community classifications as Braun-Blanquet (Westhoff and van der Maarel 1980). The following essential positions summarize his approach:

1. Vegetation is organized into recurrent units or associations having distinguishable floristic composition, which must be analyzed to develop a classification of vegetation communities.
2. Not all species in associations have equal importance for the identification of communities. Only some species may be regarded as diagnostic. Diagnostic species are divided into three categories: characteristic species, differential species, and constant companions.
3. Diagnostic species can be revealed by certain methods of comparing plant species lists of field samples ("relevés") both inside the same associations and among associations.
4. Basic units, or associations, can be organized into a hierarchical classification, where different diagnostic species or taxonomic groups can be criteria for the determination of classes on different hierarchical levels.
5. Classification is made using induction (bottom up).
6. All levels of the classification are based on a floristic approach.

Since the 1920s, this has been the dominant method used in all European countries excluding Scandinavia and Russia. In the 1930s and 1940s, it was accepted in Scandinavia and in the 1970s and 1980s, it started to be widely applied in Russia. In the 1940s, a modification of the Braun-Blanquet approach was developed in Russia by Kliopov, but his work remained unknown until it was published in 1990 (Kliopov 1990). In this approach species are grouped according to their geographical centers, and based on this, one can calculate the percentage of geographical affiliation for any given association and field plot.

The Braun-Blanquet floristic approach became popular recently in the United States for local classifications (Nakamura and Grandtner 1994; Peinado et al. 1994; Walker et al. 1994). A modification of this approach was developed by Daubenmire (1952), who narrowed its application to late successional vegetation.

In Canada, this method has been applied generally in the east (Dansereau 1959, 1972; Grandtner and Vaucamps 1982). Several current ecosystem classifications in Canada use the Braun-Blanquet approach with some additions (see sections 5.8, 5.10, and 5.12).

In the late 1980s and 1990s, the process of accumulating over geographically ample and diverse regions uniform data collected and classified using the Braun-Blanquet method began in Europe, Russia, and North America.

In Europe, a program called the European Vegetation Survey has facilitated the amalgamation of regional and national classifications into a uniform system for data collecting and defining vegetation associations. This process will result in a standardized European classification based on the Braun-Blanquet approach (Mucina et al. 1993). The process started in April 1988, when the Commission for the Prodrome of European Plant Communities was established. Twenty-five European and Asian countries (including the European part of Russia, Kazakhstan and Turkey, the Aegean Islands, the Canaries, Svalbard, and Iceland) are now represented in the network (Rodwell et al. 1995) and they have a shared commitment to:

- set common data standards in the provision of phytosociological information about plant associations;
- encourage national programs of vegetation survey across Europe;
- develop software and an electronic network for data exchange; and
- produce an overview of European vegetation.

Also, a synopsis of vegetation classes of the world was proposed (Pignatti 1990).

In Russia (including European and Asian parts), this process has also begun intensively (about 1000 associations are registered and described) (Korotkov et al. 1991; Mirkin et al. 1988), but the Asian part of Russia does not have as much financial support as the European part.

In North America, this process has achieved a much more advanced stage due to activity of the nongovernmental organization the Association for Biodiversity Information (ABI) (see section 4.7.2.1).

The logical result of this development should be a single, common list (prodromus) of vegetation communities based on the Braun-Blanquet approach throughout the world.

4.3 Structural Dominance Classifications

In these classifications plant communities are determined by the dominant species present in each stratum. Classifications of

this type were developed in Russia (Sukachev 1910, 1915, 1944) and in Sweden (Du Rietz 1921, 1930). Both of these scientific schools applied their classifications to boreal forests—ecosystems with evident vertical structure and recurrent dominance of relatively few species in the understory, grass, and moss levels. In Russia, Sukachev's classification was later incorporated as a composite part in the nationwide standard forest ecosystem classification (see section 4.7.1).

4.3.1 Structural dominance classification of Sukachev

In his work on forest classification, Sukachev furthered the forest typology work of the well-known nineteenth-century forest scientist Morozov (1912). According to Sukachev, vegetation communities were determined by dominant (edificator) species in each stratum of a vegetation community: canopy, undergrowth, grass level, and moss level. Dominant species could be identified in the field during a brief reconnaissance, and by the end of a field day a classifier could have a preliminary list of vegetation communities growing in the area. Under this approach, other characteristic species usually closely affiliated with a natural community were not regarded as important for discerning communities. In the boreal taiga forest of European Russia and Siberia, this method provided quite good results due to the general floristic poverty of forest types. Later, application of the Braun-Blanquet method for boreal forest ecosystems provided in most cases the same list of associations, though there were some exceptions. For example, comparison of *Pinetum silvestri–Vaccinium myrtillosum* sites in European Russia with analogous sites in Bulgaria by Dylis (1969) indicated that these were two different associations with different characteristic species, albeit with the same dominants both in the canopy and grass strata.

Nevertheless, structural dominance classification was successfully applied to forest inventories. The first complete inventory of the vegetation of Russia, including mountains and unpopulated areas, was completed in the mid-1950s. This resulted in the publication of a detailed vegetation map of Russia with two volumes of descriptions (Lavrenko and Sochava 1954, 1956). However, the legend of this map was not based on a consistent classification. Where there were available field data (all forests and some other ecosystems), the Sukachev classification was used; however, for mountains, tundra, and deserts lacking field data, the physiognomic approach was used.

Another important feature of the Sukachev classification was that all associations were arranged along some natural gradient: soil moisture, soil fertility, salinity, aeolian activity, movement of groundwater, portion of atmosphere precipitation versus groundwater in the hydrologic and nutrient budget, etc. Ordinated associations were called "ecological series" by Sukachev (1915). The Sukachev classification was first presented to the scientific community in 1915 and almost immediately gained broad support in Russia. (The term ecological series and the corresponding idea of ordination communities along a gradient of environment parameters was first developed and published by Keller [1909]). Later, in 1917 and 1928, Sukachev introduced a hierarchical natural community classification consisting of three levels: associations, formations, and vegetation types. Since that time, Sukachev's terminology and classification have been the most widely accepted in Russian phytocoenology and later were used to develop a national forest ecosystem classification in the 1950s (Vorobyev 1953, 1960) (see section 4.7.1).

4.3.2 Classification of Du Reitz (Uppsala School of Phytocoenology)

Du Rietz's (1930) classification was hierarchical. The most elementary units were much smaller than associations (elementary units of other schools) and were called sociations. At the second level they united into consociations and only the third level represented associations. This is a distinctive feature of this school. Associations were recognized by dominants in each stratum. Above the associations level were federations, subformations, and formations, which were identified by floristic criteria.

Another feature of this classification was adopted from Clements' (1916) classification. Phytocoenoses recognized as "climax" types were considered a core of the classification, whereas different names were proposed for seral types. For seral analogs of sociations, consociations, associations, etc., such terms as socies, consocies, associes were proposed.

The works of this school had a significant influence in Europe in the 1920–1930s, but now they are mainly only of historical interest because the founder of the school, Du Rietz, changed his conceptual views, and the Uppsala school has become largely part of the expanding sphere of the school of Braun-Blanquet (Trass and Malmer 1973). The original position of this school was that there are among natural communities clearly defined, sharply bounded natural units analogous to species units in the Linnaeus taxonomy (Linnaeus also developed his classification in Uppsala). This definition is different from that of the Braun-Blanquet school (Whittaker 1962) and that of the Russian structural dominance school (Sukachev 1915), where association is regarded as a useful convention. However, both Braun-Blanquet and Sukachev were opposed to the continuum concept (see section 4.5).

4.4 Phytotopological Classifications

Vegetation communities are subject to successions. There have been numerous attempts to exclude successional fluctuations and results of accidental disturbances and to classify types of localities, or sites, appropriate for different types of climax vegetation (Clements 1916). Phytotopological classifications use

both vegetation composition and edatope parameters, mainly those of the soil and those of the water regime, to classify its elements.

The first phytotopological classification was developed by Pogrebnyak (1929) for the vast forest region of Ukraine and Belarus (Polesie region). The main invention of this classification was an edaphic grid consisting of two coordinates: soil moisture and soil fertility. (The idea was proposed by Alekseev and elaborated by Pogrebnyak.) In his classification, Pogrebnyak identified four grades of fertility and six grades of moisture. In total, the grid consisted of 24 cells, which he called "types of site" ("tip mestoobitania"). Each of the 24 types of site received its own name based on folk terminology. Grades along the moisture coordinate were named "hydrotopes", while those along the fertility coordinate were called "trophotopes". For each cell of an edatope grid, a certain regional type of late-successional forest was affiliated. Zonal vegetation was considered as occupying the central part of the edatope grid. Sukachev's dominance-types were used for classifying forests (although both Sukachev and Pogrebnyak used the term "association"). All successional forest types were classified too and referred to a certain cell of the edatope grid. Thus, each cell contained a chronological series of forest types (which were called stand types) ending with a stable community (only they were called forest types; thus forest types were kinds of potential vegetation for a corresponding site).

Phytotopological classifications based on the Alekseev–Pogrebnyak's idea of edatope (edaphic) grid later gained a wide recognition in many countries, especially in forest ecosystem classifications. In Canada this approach was first used by Krajina (1959, 1965).

As their components, these classifications include edatope (soil ecological) classifications.

4.4.1 Edatope classifications

Edatope classifications, or ecological soil classifications, focus on major, stable soil, and hydrological characteristics that are important for vegetation and other components of biota. Along with position in relief and drainage, edatope provides a link between site classification and natural community classification. Soil parameters such as mineral or organic composition, granulometric composition for mineral soils, form of humus for organic horizons, depth appropriate for rooting, moisture regime, and nutrition regime are used for developing these classifications.

Whereas soil genetic classifications were developed within the soil science paradigm and reflect the origin of soils, edatope classifications consider soil only as a substrate for growing in a functioning ecosystem. An example of edatope classification is the soil classification developed by Sims et al. (1989) as a part of a forest ecosystem classification for Northwestern Ontario (see section 5.10.5.2).

4.4.2 Site classifications

Ideally, a site unites the entire possible range of vegetation communities that can grow in particular limits of abiotic conditions. Abiotic conditions are considered relatively stable and independent from the biotic community occupying the given locality. In reality, abiotic conditions often depend on current and preceding natural communities. These classifications identify land unit classes by climate, edatope characteristics, position in relief, drainage, and vegetation. One site can support several vegetation communities, but only one of them is usually considered a climax community. In reality, theoretical climax can be achieved rarely, and seral vegetation communities replace each other in time due to successions and effects of natural and anthropogenic disturbances. The units of these classifications are "site" and "ecosite" in English literature, "Standortsformen" in German literature, and "tip mestoobitania" in Russian literature.

4.5 Ordination Approach

The ordination approach commonly corresponds to the "continuum" concept of vegetation cover. This concept rejects the existence of natural communities as units of species that are adapted to live together. According to the continuum point of view, every species distributes itself independently according to its environmental requirements. If the same set of species is recurrently observed together, it means that the requirements of these species coincide in these localities. Consequently, there are no borders between natural communities; if one observes sharp borders, it means that abiotic conditions change sharply and go beyond the requirements of several species simultaneously. However, the ordination approach is just a method of vegetation cover analysis regardless of the conceptual position of a researcher.

Formally the ordination approach cannot be regarded as one of the natural community classifications; nevertheless, its elements are used in some classifications.

4.5.1 Ordination along environmental gradients

This is a method of arrangement of natural communities that is different from the classification approach. Communities are arranged along axes representing gradients of environmental parameters, such as temperature regime, precipitation regime, soil moisture regime, soil salinity, etc.

Also, three topological kinds of natural community ordination have been suggested:

Landscape ordination or ordination along catena— This method was first proposed by Dimo and Keller (1907), where a series of natural communities along environmental gradients was termed "ecological series". This method was further developed by Sukachev (1915) and later applied in numerous classifications as an additional method.

Zonal ordination—This type of ordination arranges natural communities that are normally distant from each other into zonal series along climatic gradients. Zonal ordination is used mainly in physiognomic classifications. Beard (1944) suggested using the term "formation series" for this type of ordination.

Ordination along vertical zones in mountains—This type of ordination is an intermediate between the first and second types. It is associated with many classification systems.

4.6 Ordination Approach and Ramensky's Classification

A very different approach from all the above classifications was developed by Ramensky (1910, 1925, 1952). Ramensky was an advocate of a "continuum" concept of vegetation (see section 4.5). According to him, each species independently chose appropriate habitats according to its requirement of environmental parameters: moisture, light, temperature, soil aeration, salinity, etc. Each species had its own limits and optima on gradient ordinates of these parameters. Ramensky developed a method of ordination and ordinated most of the common grass species of European Russia along 9–11 environmental gradients using a 100-grade scale for each of them.

Ramensky used this ordination analysis to classify simultaneously grassland associations and their sites. He chose species with broad ecological amplitudes to classify upper hierarchical levels of his classification, species such as *Festuca elatior* (meadow fescue) and *Deschampsia caespitosa* (tufted hairgrass). Each of these species can grow in a relatively wide variety of environmental conditions. Species with more narrow requirements of environmental conditions were chosen for determination of lower levels of his classification. Thus, the names of Ramensky's associations consisted of sets of species names from species with broad ecological amplitude to species with narrow amplitude. At the end of the 1960s, Ramensky's classification was supported by a large database consisting of more than 20 000 field samples ("relevés" or plot descriptions). Field samples were collected broadly over different natural zones of Russia except in the tundra and the northern taiga.

One of Ramensky's important ideas was that after ordination of common species along environmental gradients, one could quantitatively identify the environmental parameters of a site by its vegetation. In fact, his classification was a site classification, where numerous vegetation components were used to judge environmental conditions.

Ramensky's approach and classification was not accepted by other scientific schools until the 1960s when his classification was adopted as a standard classification for natural pastures and hayfields by the Russian Ministry of Agriculture. Since then and until recent time, all grasslands in Russia were inventoried and mapped using this classification. An illustration of Ramensky's classification is presented in Figure 5.

Most of Ramensky's works are in Russian and German. In the English literature, an overview of this approach was given by Sobovev and Utechin (1973).

4.7 Composite Classifications

4.7.1 Structural dominance / phytotopological / regionalization classifications

A combination of Sukachev's structural dominance classification with Pogrebnyak's phytotopological classification and with a natural regionalization allowed for the development of a standard forest ecosystem classification in Russia for all forested lands, including those in both plains and mountains (Vorobyev 1953, 1960). Three principal taxonomical axes were identified in Vorobyev's forest ecological classification:

1. **Edatope,** or forest site, **type**—Edatopes reflect similarity of sites in terms of soil and hydrology. Apart from the 24 main edatopes, some were further subdivided into edatope variants to express the influence of moisture dynamics, salinity, acidity, and some recurrent disturbance factors such as flooding. Edatope variants can be further subdivided into edatope morphs according to soil texture and slope steepness. In different climates, localization of edatope types in a landscape may be different. Edatopes having average conditions, neither too favorable nor too restrictive (mesic position of landscape according to Vysotsky 1909), were considered to reflect medium zonal conditions and were therefore called zonal type.

2. **Forest type**—This term was used to reflect not only the current but all derivatives of the potential zonal vegetation that can grow on the edatope under the climatic condition of the particular climatic region. This term reflects Dokuchaev's (1883) idea of zonal vegetation but was elaborated to include a variety of vegetation community groupings corresponding to a variety of edatopes in each climatic region. Thus, forest type unites climax vegetation and all its derivatives for a particular edatope. Unlike edatope, which reflects only soil and hydrology conditions, forest type unites ecosystems by soil, hydrological, and climatic conditions. Each natural region has its own set of forest types. Compared to other classification systems one can say that Vorobyev's forest type subclassification is in fact a potential vegetation classification assuming multiple climax types for each region. It is a site classification with every site type named by a potential vegetation type.

Mature and overmature forests having no signs of management and recent disturbances have been investigated in all climatic regions to determine a list of forest types. The oldest forest associations growing on different edatopes, edatope variations, and edatope morphs were perceived as potential or climax vegetation types (Clements 1916). The idea was that with time, current vegetation growing on similar edatopes will approach these climax types if nothing intervenes. Sukachev's methodology for determining forest type associations was generally applied. In addition to Sukachev's methodology, forest productivity was also considered.

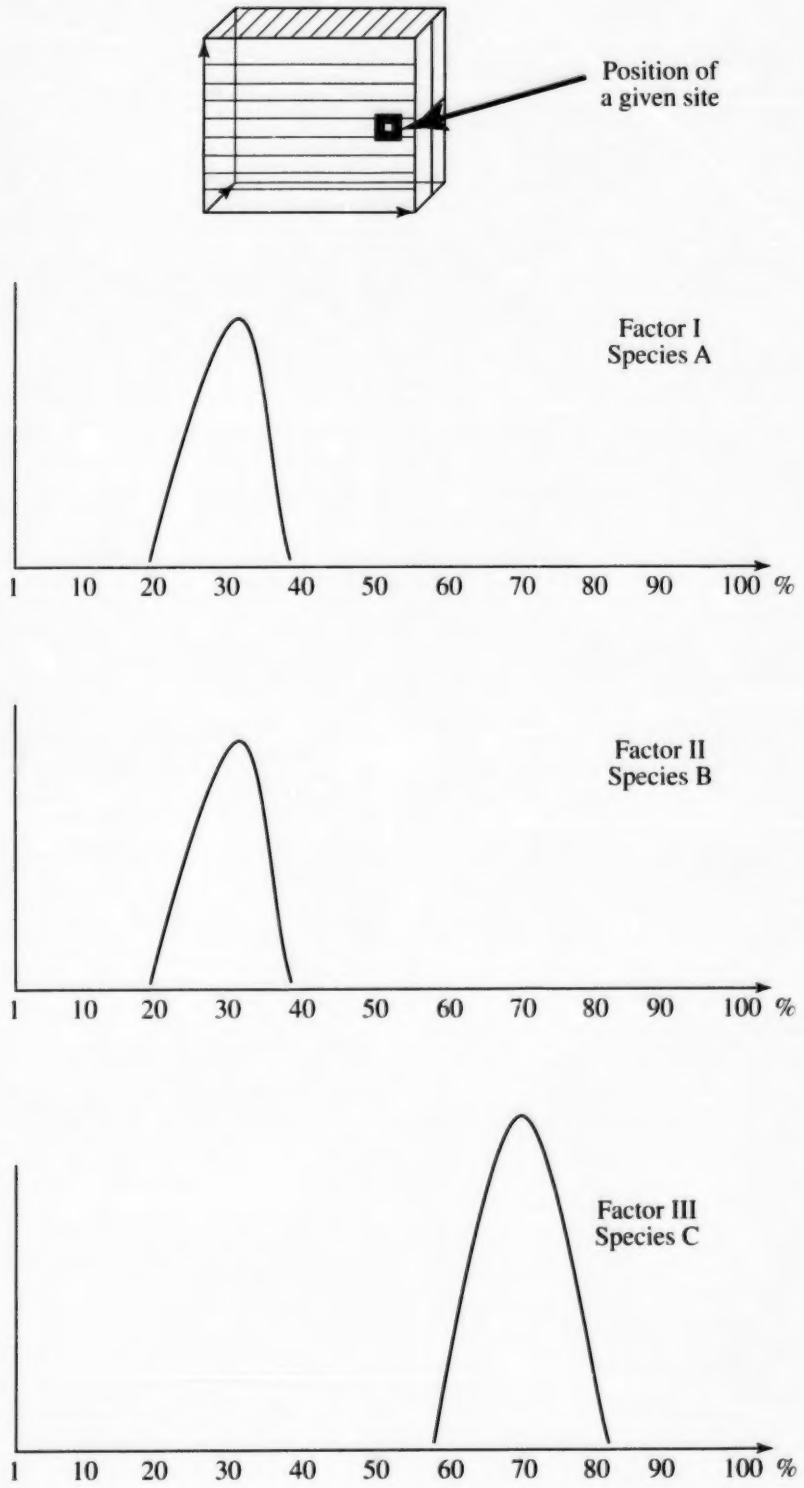
Position of
a given site
Factor I
Species A
1 10 20 30 40 50 60 70 80 90 100 %
Factor II
Species B
1 10 20 30 40 50 60 70 80 90 100 %
Factor III
Species C
1 10 20 30 40 50 60 70 80 90 100 %

Figure 5. Position of a given site in a three-factoral space using Ramensky's approach.

In plains, one (rarely two) forest types usually correspond to each edatope cell. In mountains, however, the number of forest types can be greater because of a combination of local factors leading to microclimate peculiarities.

Forest types can be mapped regardless of current vegetation. These maps were used as tools for developing forest management strategies.

3. **Stand type**—This term was used to classify existing vegetation, which can be of natural origin or reflect past forest management and other anthropogenic effects. Stand types (forest associations or dominance-types) have been determined in this classification according to Sukachev's methodology by structural dominance. In each stratum, so called edificator (dominant) species have been identified. Stand types are united into families. Among stand types some coincide with forest types, while others are considered their derivatives.

This forest classification was closely connected with the physiographic division (regionalization) of Russia. The whole country was divided into climatically homogeneous natural zones, provinces, and regions and for each of these natural regions a set of forest types was determined. The stand types were classified for the entire country. This type of combination between an element-based classification and a regionalization is also discussed in section 6.5 and shown in Figure 11.

In practice, many indicator species were used for the identification of edatopes and forest types. Throughout Russia, more than 1600 forest plant species including trees, shrubs, grasses, mosses, and lichens have been identified as indicators. Some species are used as indicators in some regions, but not in others. Hundreds of people participated in this classification work. They were mainly affiliated with scientific institutions and the state agency "Lesoproect", an agency specially designed for forest inventories.

4.7.2 Floristic / physiognomic classifications

Previously (see section 4.5) we described why vegetation communities should be chosen to identify natural communities. The necessity to combine the floristic and physiognomic approaches in one classification that would be applicable locally and globally was discussed by Beard (1973).

Long ago ecologists realized that both the floristic approach and the physiognomic approach alone have their own limitations. The floristic approach is appropriate when a researcher works with relatively similar vegetation in a certain region and consequently it is most suitable for local and regional vegetation classifications. At the macroregional and global classifications, this approach does not allow high hierarchical levels to be arranged into a limited number of types having ecological meaning. However, at the general level of consideration, physiognomic units possess some common ecological qualities regardless of the component species. This is why physiognomic classifications fit well at macroregional and global levels, but show a lack of detail at local and regional levels. Combination of the two approaches would allow combination of the advantages of both approaches and permit linking of local and global classifications into one classification. The first attempts to combine these two approaches into a single hierarchical classification were undertaken in the nineteenth century. Hampus von Post (1851) developed one of the first classifications of this type for central Sweden. Nevertheless, during most of the twentieth century, no well-elaborated floristic/physiognomic classifications were developed, although some floristic classifications had the highest physiognomic levels. The task for a single classification to be equally applicable to any local area and for an ample macroregion never had enough driving forces to be implemented. The limiting factor was the lack of uniformly collected and classified data at the lowest floristic level. Whereas the process of unification of the lowest floristic units began in the 1980s in Europe, Russia, and the United States (see section 4.2.1), significant progress was made in the United States when The Nature Conservancy, a nongovernmental international organization dedicated to protecting biodiversity, decided to combine these floristic units with upper physiognomic levels (Grossman et al. 1994).

4.7.2.1 International classification of ecological communities—The Nature Conservancy (TNC), in partnership with the network of Heritage Programs and Conservation Data Centres and the Association for Biodiversity Information (ABI), has developed the International Classification of Ecological Communities (ICEC) (Grossman et al. 1998). This system has existed in various forms for over 25 years. The development of this classification was spurred by a practical necessity to have a decision-making tool for conservation applications. TNC's mandate to preserve biodiversity includes species of all taxonomic groups and ecological communities. A standard ecological community classification applicable at a local level and emphasizing biodiversity information was considered a necessary tool for deciding which sites should be preserved. The ICEC system uses vegetation as the basis of its classification, and for reasons stated previously (section 4.7.2) uses both physiognomic and floristic criteria. The system has been fully developed in the United States as the U.S. National Vegetation Classification System (US-NVC). The development of the US-NVC began in a similar context to that of the current situation in Canada, in that numerous local vegetation classifications had been developed in different jurisdictions. Many of these were developed by state Natural Heritage Programs that were established by TNC in conjunction with state governments to conduct ecological surveys for high quality natural habitats, for example, in Illinois (White and Madany 1978), Missouri (Nelson 1985), New York (Reschke 1990), and North Carolina (Schafale and Weakley 1990). These systems used a combination of physiognomy, floristics, and abiotic site characteristics for identification of their elements. Although working well at the state level, these

Table 1. Hierarchical levels of the United States National Vegetation Classification (Grossman et al. 1998).

Level	Primary Basis for Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g. leaf phenology	Deciduous Woodland
Group	Leaf type, corresponding to climate	Cold-Deciduous Woodland
Subgroup	Relative human impact (natural/seminatural, or cultural)	Natural/Seminatural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporary Flooded Cold-Deciduous Woodland
Alliance	Diagnostic/dominant species of uppermost or dominant stratum	*Populus deltoides* Temporary Flooded Woodland Alliance
Association	Additional diagnostic/dominant species in all strata	*Populus deltoides (Salix amygdaloides)/ Salix exigua* Woodland

classifications were not consistent with each other, which did not allow the states' conservation efforts to be prioritized nationally and internationally. All this pointed to the need for a nationwide and indeed worldwide ecological community classification that would have a high resolution locally and encompass as much as possible the local classifications. The ICEC system was developed through a long process of multilateral collaboration led by TNC and ABI. Natural Heritage Programs and government agencies of the United States, as well as several scientific institutions, also participated.

A key component of the overall task was to develop a system that would work in the United States but that would also be applicable internationally. TNC chose to work with a physiognomic classification, the UNESCO world vegetation classification (UNESCO 1973; see also section 4.1.1). Several factors contributed to this decision. First, the UNESCO classification is the result of an international collaboration of scientists with considerable vegetation expertise and has been used in many parts of the world. Second, it has a hierarchical arrangement, allowing it to be used at various conceptual scales, depending on the level of detail available or needed for a specific purpose. Third, its units are vegetation formations, that is, vegetation types defined by physiognomy, with clear identification criteria associated with each. This means that the system creates standard, easily identifiable units that may apply to many areas of the globe. Finally, the UNESCO formation levels contained associated ecological criteria (especially climate, topography, and hydrology) that helped define the units more geographically.

ABI and TNC made some amendments to the UNESCO classification to provide better representation of physiognomic conditions and more coherent links to floristic levels, which are not included in the UNESCO classification. An additional level was added between the "formation" and "group" levels to allow a separation between cultural vegetation (for example, corn fields, plantations) and natural vegetation. The ICEC system uses floristic units at the lowest levels (the association and alliance) that are similar in many respects to the Braun-Blanquet approach. These floristic units are nested within the physiognomic units. Table 1 presents the scheme of hierarchical levels as used in the ICEC (Grossman et al. 1998). In developing the U.S. portion of the ICEC, ABI and TNC relied heavily on secondary sources, such as state Heritage Program classifications, habitat type classifications, and many published articles, as well as some de novo field surveys and data analyses, to establish a first approximation of these floristic units.

The U.S. portion of the ICEC has gained many additional applications in the United States. It is used by the U.S. Geological Survey's Gap Analysis Program (GAP)[2] (Jennings 1993). It is also used by the National Biological Service/National Park Service Vegetation Mapping Program for National Parks (Grossman et al. 1994). Together with the U.S. Forest Service Ecological Land Classification, the US-NVC was used to characterize the vegetation component of ecological land units (Keys et al. 1995), demonstrating its ability to be used in conjunction with an ELC approach. In 1997, the US-NVC was adopted by the U.S. government as the "Federal Geographical Data Committee Vegetation Classification and Information Standards" (though only the upper physiognomic levels were fully described at that time), to be used as a national standard for reporting all vegetation data by federal agencies

[2] The National Gap Analysis Program (GAP) (Scott et al. 1993) is the first state- and national-level effort to complete a series of existing vegetation and land cover maps based on satellite imagery data. Products include a map of existing natural vegetation to the level of dominant or codominant species (alliances or groups of alliances). The US-NVC was adopted for this purpose.

(FGDC 1997). In the mid-1990s, the Ecological Society of America (ESA) recognized the US-NVC as a basis for developing comprehensive standards for a vegetation classification of the United States. Since then ESA has been assisting with the ongoing work on classification refinement and the definition of standards (Loucks 1996; Glenn-Lewin 1999).

The ICEC system has also been applied in other Western Hemisphere countries such as Mexico, Puerto Rico, Jamaica, and Cuba, as well as here in Canada. As noted previously, the support of ABI and TNC for Conservation Data Centres has led to a direct collaboration in supporting the development of the system in those countries.

5. Canadian Classifications

5.1 Ecological Land Classification (ELC)[3]

This is the most elaborate nationwide regionalization type of classification in Canada. The development of this classification has a long history starting from the establishment of the Canada Land Inventory Program in 1963. In 1976, the Canada Committee on Ecological Land Classification was created to encourage development of this system (Ironside 1989). "In this approach the entire landscape is parceled into contiguous units having ecological significance and which display a limited number of diagnostic features which are used in their delineation" (Welch 1978).

There is no single "leading" factor responsible for the delineation of ecounits on different hierarchical levels. Criteria for the delineation of ecounits at different hierarchical levels are relatively similar as we can see from their definition (Ecological Stratification Working Group 1995):

Ecozone—an area of the earth's surface representative of large and very generalized ecological units characterized by interactive and adjusting abiotic and biotic factors.

Ecoregion—a part of a province characterized by distinctive regional ecological factors, including climate, physiography, vegetation, soil, water, fauna, and land use.

Ecodistrict—a part of an ecoregion characterized by distinctive assemblages of relief, geology, landforms and soils, vegetation, water, fauna, and land use.

The different levels of the ELC correspond to the scales at which they can be mapped (Wiken et al. 1981):

Ecoprovince	1:5 000 000	to	1:10 000 000
Ecoregion	1:3 000 000	to	1:5 000 000
Ecodistrict	1:500 000	to	1:1 000 000
Ecosection	1:50 000	to	1:250 000
Ecosite	1:10 000	to	1:25 000
Ecoelement	1:2 000	to	1:5 000

The main application of the ELC is a spatial framework for organizing a monitoring network and for environmental reporting needs. The framework may be viewed "as a directory and the ecological units as a comprehensive set of information folders" (Ecological Stratification Working Group 1995).

Canada is divided into ecozones and at the intermediate hierarchical levels into ecoregions and ecodistricts. Lower hierarchical levels (ecosection, ecosite, and ecoelement) have not been identified for the whole country (Wiken 1986; Groupe de travail sur les écorégions, Comité canadien de la classification écologique du territoire 1989; Wiken et al. 1993; Ecological Stratification Working Group 1993, 1995; International Working Group 1997). Terminology at the lower levels is not always consistent with that proposed by the Ecological Stratification Working Group. In Saskatchewan, for example, the term "ecological area" is used instead of "ecodistrict".

5.2 Provincial Ecological Regionalization Systems

Canadian provinces have developed their ecological regionalization systems, and some of them are consistent with the ELC. Other land regionalization systems have mapping units that do not correspond to the ELC.

Some provincial ecological regionalization systems are:

- Ecoregion Classification of the British Columbia Ministry of Environment, Land and Parks (ecodomains, ecodivisions, ecoprovinces, ecoregions, and ecosections) (Demarchi 1988, 1991)
- Zonal, or Climatic Classification, a component of the British Columbia Biogeoclimatic Ecosystem Classification

[3] This term is used with three different meanings. In this report, we use the term ELC with its second meaning:

1. "Ecological Land Classification" is a generic term for a spatial hierarchical 'latticework' (Sims et al. 1996) where land units of higher hierarchical levels are successively divided into land units of lower hierarchical levels. In other words, "Ecological Land Classification" is a hierarchical landscape division.

2. "Ecological Land Classification" is a particular hierarchical system proposed by the Canada Committee on Ecological (Biophysical) Land Classification in 1978 that included four hierarchical levels that are currently called ecoregion, ecodistrict, ecosection, and ecosite (LeSauteur and Savoie 1980). Three other levels, namely ecozone, ecoprovince, and ecoelement, were later added to the upper and lower levels of the hierarchy (Environmental Conservation Service Task Force 1981; Ironside 1991).

3. "Ecological Land Classification" is a combination of both division and element-based classification in a single hierarchical scheme as well as some other activities (Lee et al. 1998).

(biogeoclimatic zone, biogeoclimatic subzone, biogeoclimatic variant, and biogeoclimatic phase) (Pojar et al. 1987)

- Alberta Natural Region Land Classification System (Achuff and Wallis 1977; Alberta Environmental Protection 1994)
- Ecoregions of Alberta Classification (Strong and Leggat 1981)
- Physiographic divisions of the Northern Saskatchewan Forest (Ellis and Clayton 1970)
- Hills's site classification of Ontario (Hills 1952, 1961)
- Ecological Reference Framework of the Ministère de l'Environnement et de la Faune du Québec (Li et al. 1994; Ducruc et al. 1995)
- Classification écologique du Québec (Saucier et al. 1998a; Saucier et al. 1998b; Bergeron et al. 1998)
- New Brunswick Site Region Classification (van Groenewoud 1984)
- Ecoregions and subregions of Insular Newfoundland (Damman 1983)

5.3 Other Ecological Land Divisions

Rowe (1972) developed a forest regionalization for Canada in which the country is divided into 8 forest regions and then into 99 forest districts. Some provincial forest ecosystem classifications in Canada use Rowe's forest regions as land units to which these classifications are applicable.

The Wetland Regions of Canada was developed by the National Wetlands Working Group (1986). In these two divisions, land units do not match those of the ELC.

5.4 Canadian Vegetation Classification System (CVC), First Approximation

In 1990, The National Vegetation Working Group of Canada Committee on Ecological Land Classification proposed an outline of a Canadian vegetation community classification (National Vegetation Working Group 1990).

The proposed classification has seven hierarchical levels (Table 2) defined by community physiognomy, species dominance, and floristic criteria. The four upper physiognomic levels (Levels I–IV) have been completed, but for the remaining three lower floristic levels (Levels V–VII), only general guidelines for development have been proposed. The authors stated that "...potential permutation of species and our current understanding of vegetation makes detailed presentation for Level V though VII impractical". The four upper levels of the CVC correspond to Fosberg's (1961) physiognomic classification of world vegetation formations. The classes of level I are (1) tree-dominated stand, (2) shrub-dominated stand, (3) herb-dominated stand, and (4) nonvascular-dominated stand. Level II is divided by leaf phenology (evergreen, deciduous, etc.) or predominant taxonomic group. The next two levels (III and IV) are divided into classes by very formal quantitative criteria based on canopy cover and height. The three lower floristic levels correspond to some degree to the Braun-Blanquet system. Thus, Level V is based on dominant or codominant species, which the authors state should correspond in part to the alliance level of the Braun-Blanquet system. Level VI is based on major differences in understory vegetation, and Level VII on major differences in one or more species in the understory vegetation and should generally correspond to the association or subassociation of Braun-Blanquet (National Vege-

Table 2. Hierarchical levels of the first approximation of the Canadian Vegetation Classification (CVC), with an example provided by the National Vegetation Working Group (1990).

Level	Primary Basis for Classification	Example
I	Growth form and structure of vegetation	Tree
II	Growth form characteristics, e.g. leaf phenology	Deciduous tree
III	Total stand cover	Closed
IV	Height	Tall
V	Dominant and codominant species in the uppermost stratum	Balsam poplar, *Populus balsamifera* L.
VI	Dominant and codominant species or growth form in understory strata	Balsam poplar/Saskatoon, *Amelanchier alnifolia* (Nutt.) Nutt.
VII	Additional diagnostic/dominant species in understory strata	Balsam poplar/Saskatoon/ squashberry viburnum, *Viburnum edule* (Michx.) Raf.

tation Working Group 1990). No classes were proposed for the three lowest floristic levels, but the intent was to give enough guidance that future investigators could complete these levels. See also section 6.4.

5.5 Canadian Wetland Classification (CWC)

This classification has been elaborated by the National Wetlands Working Group (1987). It embraces a four-level hierarchical wetland classification proposed by Zoltai et al. (1975) and later amended and synthesized with several regional classifications. In its current state the CWC consists of three hierarchical levels:

Wetland classes—are determined on the basis of overall origin of the wetland body and prevailing hydrological process.

Wetland forms—are identified by surface morphology, surface pattern, water type, and morphology of underlying mineral soil.

Wetland types—are recognized according to vegetation physiognomy.

5.5.1 Regional wetland classifications

Several regional hierarchical wetland classifications had been developed before the Canadian Wetland Classification and were used in part by the latter. Among these classifications are the prairie wetland classification in western Canada developed by Millar (1976), Couillard and Grondin's (1986) wet environment classification, and the wetland classification for Ontario (Jeglum et al. 1974). The wetland classification for Northwestern Ontario was developed by Harris et al. (1996). It was incorporated into the Terrestrial and Wetland Ecosite Classification of Northwestern Ontario (Racey 1996) (see section 5.10.5.2). Physiognomic and floristic criteria were used at some hierarchical levels of these wetland classifications.

A strictly vegetation classification of peatlands was developed by Wells (1996) for Atlantic Canada using the Braun-Blanquet method.

5.6 Canadian Soil Classifications

An element-based national soil classification was developed by the Canada Soil Survey Committee (1978). It consists of a few hierarchical levels that are defined by soil composition and the presence of certain genetic horizons. This classification is used for site classification in the Newfoundland forest ecosystem classification (see section 5.10.8.1), but its arrangement is not the best for this purpose. Genetic properties of soils reflect processes of their development and do not necessarily play a main role in determining soil parameters as a substrate for vegetation (edatope). This is why attempts were undertaken to develop special ecological soil classifications aimed at reflecting soil as substrate for vegetation communities. Indeed, classifications of this type were developed as parts of certain forest ecosystem classifications (see section 5.10).

5.7 Forest Inventories

Provincial and territorial forestry departments undertake forest inventories using aerial photo interpretation combined with a field component. For example, the Forestry Branch of Saskatchewan Environment and Resources Management (SERM) determines general tree associations, primary tree species, and secondary tree species based on timber volume per square unit (Frey 1981). It produces forest inventory maintenance maps (FIMM); these inventories do not usually embrace all vegetation, but rather mainly tree species (Lowe et al. 1996).

5.8 Vegetation Inventories in National Parks

Canadian national parks have detailed maps of their vegetation (for example, Edlund 1991). Unfortunately, these inventories were not all based on a consistent standard method, and it is now impossible to analyze nationally the distribution of vegetation types in national parks, although there are groups of parks that were inventoried with consistent approaches. Some national parks are located in remote areas, which are not covered by any other classifications (for example, Wapusk National Park in Manitoba, Ellesmere Island National Park in Nunavut, and many others), and so far their vegetation inventories are almost the only representation of vegetation for vast surrounding areas.

5.9 Vegetation Mapping Projects in the Canadian North

Several vegetation mapping projects have been undertaken in the Yukon and the Northwest Territories both for forested lands and tundra. Legends for these maps were developed based on a combination of physiognomic and floristic (usually forest cover types) features discernable from Landsat TM images and supported by fieldwork; for example, for the Sahtu region, 39 vegetation classes were identified (L. Robinson, personal communication). Most of this work has been done during the last few years for different land claim regions. In the Northwest Territories, the work was coordinated by the Department of Resources, Wildlife and Economic Development of the territorial government. In 1997, this department adopted a classification approach and most of the mapping projects are consistent with this approach. However, there are several studies that have been conducted by other agencies and their classification may not conform to the department's approach.

5.10 Forest Ecological Classifications (FEC)

The first forest ecosystem classifications developed in Canada used the Braun-Blanquet approach (Dansereau1959; Linteau 1959). More recently, almost all the Canadian provinces have developed their own classifications of forest ecology based on a combination

of floristic and site criteria for identification of their elements. These classifications have different names but for the purposes of uniformity we will refer to them as Forest Ecosystem Classifications, or FECs. Although these classifications have many similarities, they may have different structures and cannot be easily merged into a single national classification. Several of these classifications were developed by provincial ministries of natural resources in partnership with the Canadian Forest Service, Natural Resources Canada. A comparison of provincial FECs is given in section 5.11 and in Table 4.

5.10.1 British Columbia

5.10.1.1 British Columbia Ministry of Forests Biogeoclimatic Ecosystem Classification (BEC)—The BEC is probably the most elaborate forest ecological classification system in Canada. It is composed of four almost independent classifications: climate classification, vegetation classification, site classification, and seral classification. This system was developed by Krajina (1959, 1965, 1969) and later systematically elaborated by the British Columbia Ministry of Forests (Pojar et al. 1987; Delong et al. 1990; Lloyd et al. 1990a, b; Meidinger and Pojar 1991; Braumandl and Curran 1992a, b; Banner et al. 1993a, b; Delong et al. 1993, 1994; Green and Klinka 1994; Steen and Coupe 1997a, b).

Climate Classification—In this classification, British Columbia is divided into biogeoclimatic zones according to predominant regional climate. Two lower hierarchical levels are identified in the climate classification: biogeoclimatic subzones and biogeoclimatic variants. Sometimes biogeoclimatic variants are divided into biogeoclimatic phases, but this is not a formal category in the BEC. Although this classification is considered a climate classification, it is not the climate characteristics themselves that are used in defining and delineating all biogeoclimatic units, but the so-called zonal vegetation. Climatic division is thus manifested by vegetation.

Vegetation Classification—The vegetation classification is based on the Braun-Blanquet floristic classification (Westhoff and van der Maarel 1980). Four hierarchical levels are defined by floristic criteria as determined by Braun-Blanquet: associations, alliances, orders, and classes. Associations may be divided into subassociations. Mostly late successional ecosystems were researched and classified in this classification for practical reasons, although younger stands and seral vegetation can be easily added. Vegetation classification is element-based and applicable for the entire province.

Site Classification—Sites are classified within each of the biogeoclimatic subzones or variants. There are several site classifications, each applicable in geographically separate areas and all are based on the same principles.

Site units represent groups of sites having equivalent environmental properties and potential vegetation. The basic unit of site classification is the site series. A site series corresponds to a potential climax vegetation association in each climatic subzone and variant. Site series are subdivided into site types and site phases (the latter is not a formal category in the classification).

Site series from different climatic subzones and variants are united into site associations on the basis of common potential vegetation.

Successional, or Seral Classification—The main application of this classification is to arrange vegetation associations of different successional stages into a system. This classification is not yet well developed.

Both the climatic and the site classifications were developed by studying mature and old-growth forests.

5.10.2 Alberta

Alberta's first forest classification was developed for the west-central part of the province (Corns and Annas 1986). It was used as the basis for later ecosite classification for the same area (Beckingham and Archibald 1996), although this later classification is based on different principles. Simultaneously, several other ecosite classifications were developed for different parts of Alberta and all are based on the same principles as the west-central Alberta ecosite classification. The Alberta Natural Region Land Classification (Alberta Environmental Protection 1994) is a division that was used for defining the area of applicability of each element-based classification. Land units corresponding to each element-based classification are of different hierarchical levels: in some cases they are natural subregions, in other cases they are parts of natural subregions, and in yet others they are groups of natural subregions. The three hierarchical levels of the element-based classification are ecosite, ecosite phase, and plant community type. Soil type classification is independent and has been taken from Sims et al. (1989) with some modifications.

In total, there are 12 uniform ecosite classifications outlined in groups that follow.

5.10.2.1 Ecosites of west-central Alberta—This group of classifications (Beckingham et al. 1996a) was elaborated for portions of the Foothills and Rocky Mountains natural regions of west-central Alberta, which are divided into five natural subregions (Lower Foothills and Upper Foothills are subregions of the Foothills natural region; Montane, Subalpine, and Alpine are subregions of the Rocky Mountains natural region) (Beckingham et al. 1996a). The Alpine natural subregion is not covered by this group of classifications.

The classifications are made separately for each natural subregion. In total, there are four ecosite classifications:

- The Lower Foothills Ecosite Classification. Fourteen ecosites, 30 ecosite phases, and 74 plant communities.
- The Upper Foothills Ecosite Classification. Eleven ecosites, 30 ecosite phases, and 65 plant communities.
- The Montane Ecosite Classification. Seven ecosites, 22 ecosite phases, and 36 plant communities.

- The Subalpine Ecosite Classification. Eight ecosites, 13 ecosite phases, and 51 plant communities.

5.10.2.2 Ecosites of southwestern Alberta—This group of classifications (Archibald et al. 1996) is made for portions of the Foothills and Rocky Mountains natural regions of southwestern Alberta, which are divided into four natural subregions (Lower Foothills, Upper Foothills, Montane, and Subalpine and Alpine). However, the Alpine natural subregion is not covered by this group of classifications. The classifications are developed separately for each natural subregion. In total, there are four ecosite classifications:

- The Lower Foothills Ecosite Classification. Eleven ecosites, 23 ecosite phases, and 42 plant communities.
- The Upper Foothills Ecosite Classification. Eleven ecosites, 22 ecosite phases, and 45 plant communities.
- The Montane Ecosite Classification. Seven ecosites, 17 ecosite phases, and 26 plant communities.
- The Subalpine Ecosite Classification. Eight ecosites, 13 ecosite phases, and 25 plant communities.

5.10.2.3 Ecosites of northern Alberta—This group of classifications (Beckingham and Archibald 1996) covers the Boreal Forest natural region and the Canadian Shield natural region of Alberta. The Boreal Forest natural region is subdivided into six subregions: Central Mixedwood, Dry Mixedwood, Wetland Mixedwood, Subarctic, Peace River Lowlands, and the Boreal Highlands. The Canadian Shield natural region is divided into the Athabasca Plain and the Kazan Uplands natural subregions. This group of classifications uses a new regionalization level between the region and subregion levels—ecological area (EA). Each ecological area includes one or more subregions. The classifications are developed separately for each ecological area. Central Mixedwood, Dry Mixedwood, Wetland Mixedwood, and Peace River Lowlands subregions are united into the Boreal Mixedwood ecological area. The Subarctic and the Boreal Highlands natural subregions correspond to their own ecological areas. The Canadian Shield represents the fourth ecological area. In total, there are four element-based ecosite classifications:

- The Boreal Mixedwood Ecological Area Ecosite Classification. Twelve ecosites, 25 ecosite phases, and 73 plant communities.
- The Boreal Highlands Ecological Area Ecosite Classification. Ten ecosites, 18 ecosite phases, and 29 plant communities.
- The Subarctic Ecological Area Ecosite Classification. Eight ecosites, 19 ecosite phases, and 27 plant communities.
- The Canadian Shield Ecological Area Ecosite Classification. Eight ecosites, 15 ecosite phases, and 20 plant communities.

5.10.3 Saskatchewan

5.10.3.1 Ecosites of the Mid-Boreal Ecoregions of Saskatchewan—The design of this classification (Beckingham et al. 1996b) is the same as the ecosite classifications in Alberta and was elaborated for the Mid-Boreal Subzone, which includes two ecoregions: Mid-Boreal Upland and Mid-Boreal Lowland. Mid-Boreal Upland is subdivided into 30 landscape areas, whereas Mid-Boreal Lowland is subdivided into 4 landscape areas. A common element-based classification is used for these two ecoregions and all 34 landscape areas. This classification has three levels: ecosite, ecosite phase, and plant community type. These three levels are arranged in a strict hierarchical subordination. Ecosite is determined by its position in the edatope grid, and it can have different vegetation and different soils. Ecosite phase groups vegetation: it is analogous to alliance in the limits of ecosite in that it is determined by dominant canopy species. Plant community type is subordinate to ecosite phase. Plant community type is determined by characteristic species and their prominence values. Plant communities are strictly restricted by one ecosite. There are 13 ecosites, 23 ecosite phases, and 78 plant community types.

5.10.4 Manitoba

5.10.4.1 Forest ecosystem classification for Manitoba—This classification (Zoladeski et al. 1995) is applicable to the Boreal Forest zone and to the Manitoba portion of the Great Lakes–St. Lawrence forest region (Rowe 1972). Under the ELC it contains parts of the Boreal Shield and Boreal Plain ecozones (Ecological Stratification Working Group 1993). This classification does not include the northern part of the province where no commercially valuable forests occur. Thirty-three vegetation types are defined in this classification. The Northwestern Ontario forest ecosystem classification (Sims et al. 1989) was used as a model, with some modifications. Vegetation types are defined by dominant species of the overstory and by differential species of other strata. Five hundred and eighty plots were used for developing the classification. Soil type classification is independent in this system. Soils are differentiated by thickness (deep, shallow), organic or mineral composition, texture, and water regime. Probable soil types are identified for each vegetation type. Site classification is not included in this classification.

5.10.5 Ontario

5.10.5.1 History—Forest site regionalization began in 1959 with Angus Hills's province-wide delineation and description of site zones, site regions, and site districts. Hills used climate, geology, and vegetation heterogeneity to delineate land units (Hills 1961).

Ontario's first FEC was developed for the Clay Belt, Hills's Site Region 3E (Jones et al. 1983; Arnup and Jeglum 1994). All subsequent classifications used the land regionalization of the Ontario Ministry of Natural Resources (OMNR regions). To date, classifications for the northwestern, northeastern, and central regions have been developed. The first was an FEC for the northwestern region (Sims et al. 1989). Later a wetland ecosystem classification (Harris et al. 1996) for the same region was added.

Finally, these two classifications were re-worked to produce an ecosite classification (Racey et al. 1996). Ecosite classifications were produced for two other regions, namely for northeastern and central ones (McCarthy et al. 1994; Chambers et al. 1997). The Natural Heritage Information Centre (Ontario Conservation Data Centre) has recently developed an ecosystem classification for Southern Ontario (see section 5.12.1).

5.10.5.2 Terrestrial and wetland ecosites of Northwestern Ontario—This classification was developed for the OMNR's northwest region (Racey et al. 1996). It includes Hills's site regions 5S, 4S, 4W, and 3W and portions of 3S, 2W, and 2E (Hills 1961). Hills's regions were developed specially for land use planning, but the OMNR uses a different regionalization. The whole system consists of four independent subclassifications: an ecosite classification, a vegetation type classification, a wetland type classification, and a soil type classification. Vegetation types and wetland types correlate to a certain degree to ecosite types, but the vegetation and wetland type classifications are still independent from the ecosite classification. On pictograms of the edatope grid, there are 11 grades of moisture and 3 grades of nutrition.

The **vegetation type** classification was developed by Sims et al. (1989) only for forested ecosystems including forested wetlands. The same vegetation type can be present on different ecosites and conversely one ecosite can have several different vegetation types. In total, 38 vegetation types (VT) are determined. They are grouped into three classes: Mainly Hardwood, Conifer Mixedwood, and Conifer.

The wetland classification was developed by Harris et al. (1996). **Wetland types** (WT) are determined by floristics, substrate, and physiognomy. In total, 36 wetland types are determined.

The ecological soil classification was developed by Sims et al. (1989). **Soil types** (ST) are defined on the basis of their moisture regime, mineral or organic composition, texture of mineral soils, and depth to bedrock. In total, 22 soil types are defined.

Ecosite types (ET) in this classification are defined by both soil and vegetation. All ecosite types have cross references to possible corresponding vegetation types. Ecosite classification includes recurrent complexes of vegetation types as a single ecosite. It was developed to simplify mapping. All ecosite types have cross references to possible corresponding soil types. Some ecosites have cross references to possible corresponding wetland types. For example, ecosite ES36 (Intermediate Swamp: Black Spruce [Tamarack] : Organic Soil) can be occupied by vegetation types VT23, VT35, and VT36; wetland types WT29 and WT30; and soil types ST12F, ST12S, ST11, and STS9.

Treatment unit type classification (Racey et al. 1989) identifies management-oriented groupings of VTs, WTs, STs, and ETs. In total 17 treatment unit types are defined.

An important feature of this classification is that all subclassifications (vegetation type, wetland type, soil type, ecosite type, and treatment unit type) are independent of each other. This means that they have certain correlations among each other, but there is no strict subordination at the classification design level. Identification keys for each subclassification are separate. This arrangement will be further examined in section 5.11.

5.10.5.3 Forest ecosystem classification of Northeastern Ontario—This classification (McCarthy et al. 1994) is applicable to the northeastern region of the OMNR (McCarthy et al. 1994). This includes Hills's site region 3E and parts of regions 2E and 4E. Six hundred and sixteen sample sites ("relevés") were used for the development of this classification (Nieppola et al. 1993). The classification consists of three components:

Site Type—Identifies mappable, management-oriented groupings of vegetation on specific ranges of soil conditions. Soil features, and after that vegetation features, are used as criteria for the identification of site types. Twenty-two site types are united into seven major groups: one group represents southern type ecosystems with broadleaf species, whereas the others are defined by soil properties.

Vegetation Type—Identifies mature-forest plant communities, based on specific ranges of plant species composition and abundance. Twenty-six vegetation types are grouped into seven groups by dominant canopy species.

Soil Type—Identifies groups of forest soil profiles based on texture, depth, moisture regime, calcareousness, and forest humus form. Nineteen soil types are grouped into seven groups by depth, texture, and thickness of the organic horizon.

5.10.5.4 Forest ecosystem classification of central Ontario—This classification (Chambers et al. 1997) is developed for the central region (seven districts) of the OMNR and includes portions of Hills's site regions 5E and 4E.

Ecosite types are identified by the composition of the canopy stratum. Thirty-five ecosites are grouped into five classes by predominant ecological group of tree species or by hydrological regime: (1) White and Red Pine; (2) Jack Pine and Black Spruce; (3) Intolerant Hardwoods and Mixedwoods; (4) Tolerant Hardwoods; and (5) Hardwood and Conifer Lowlands. Each ecosite is subdivided into two moisture classes according to soil features.

Vegetation classification is independent of site classification and is based on diagnostic species in all strata. In total, 41 vegetation types are differentiated. There are varying degrees of correlation between a particular ecosite and vegetation types. A vegetation type can occur on different ecosites and conversely one ecosite can be occupied by different vegetation types.

The **soil** classification is independent of both the ecosite classification and the vegetation classification. Soil types are discerned

on the basis of depth of loose substrate over the bedrock, mineral or organic composition of the substrate, soil texture, and features of a hydrological regime. In total, there are 26 soil types.

5.10.6 Quebec

5.10.6.1 Land classification system of the Ministère des Ressources naturelles du Québec—This hierarchical system is a combination of physiogeographic regionalization at its upper levels and element-based classifications at its lower levels (Bergeron et al. 1992; Saucier and Robert 1995; Bérard 1996; Robitaille and Saucier 1996; Saucier et al. 1998a, b; Robitaille and Saucier 1998). The hierarchical levels of this system are presented in Table 3.

The first nine levels in Table 3 represent division levels, whereas the last two reflect element-based levels. The same ecological types and forest types can be found in different altitudinal vegetation levels, land districts, regional landscape units, land subregions, and land regions. The overall classification system contains ecological type and forest type identification keys, one for each subdomain (Gosselin et al. 1998; Grondin et al. 1998). Thus, arrangement of this classification has a double hierarchical scheme (see also section 6.5 and Figure 11). For example, for subdomain 4E (eastern fir–yellow birch subdomain) there are 180 forest types, each of which can be found in any subordinated area within this subdomain and must be identified using the same key (Gosselin et al. 1998). Ecological type in this system is analogous to site type in the classifications of other Canadian provinces (see, for example, section 5.10.1.1, Site Classification) and to forest type in the Russian forest ecological classification (see section 4.7.1). There are 62 ecological types for subdomain 4E. In total, there are 11 uniformly designed element-based forest type and ecological type classifications for the temperate forest zone and southern part of the boreal zone of Quebec.

5.10.7 New Brunswick

5.10.7.1 Forest site classification in New Brunswick—This classification (Zelazny et al. 1989a, b) was developed under the auspices of the New Brunswick Forest Site Technical Committee, which divided the province into nine site regions (van Groenewoud 1984). Site regions were recognized on the basis of meteorological

Table 3. Hierarchical levels of Land Classification System of the Ministère des Ressources naturelles du Québec (Saucier et al. 1998a, b; Bérard 1996).

Hierarchical level	Definition
Vegetation zone, major climatic differences	Vast area, on a continental scale, characterized by the physiognomy of the plant formations reflecting major climatic differences.
Vegetation subzone	Part of a vegetation zone characterized by the physiognomy of the potential vegetation dominating the landscape.
Bioclimatic domain	Area characterized by the nature of the potential vegetation growing on mesic sites, expressing the effects of climate.
Bioclimatic subdomain	Part of the bioclimatic domain with different vegetation characteristics due to differences in precipitation.
Ecological region (ecoregion)	Area characterized by forest composition and plant dynamics on mesic sites, and by the distribution of ecological types along a toposequence.
Ecological subregion	Part of the land region where mesic site vegetation is either typical of the bioclimatic domain to which it belongs, or more northerly or more southerly.
Regional landscape unit	Area characterized by recurrent arrangement of the main permanent ecological features of the environment and the vegetation.
Land district	Area characterized by its own pattern of relief, geology, geomorphology, and regional vegetation.
Altitudinal vegetation level	Area where altitude has such a marked effect on climate that the structure and often the nature of the vegetation are changed, so that the vegetation in fact resembles that of more northerly or more southerly regions.
Ecological type	Part of the area, on a local scale, with a permanent combination of site potential vegetation and environmental features.
Forest type	Part of an ecological type occupied by a forest ecosystem whose present composition and structure are distinct.

data, bedrock and physiography, and species composition of vegetation on zonal sites. Each element-based ecosystem classification was developed for one or two site regions. In total, there are five uniform element-based classifications. Each classification consists of three subclassifications: vegetation type (VT), soil type (ST), and treatment unit type (TUT).

Vegetation types are identified by the presence or abundance of certain indicator species. Vegetation type keys are separate for organic soils, mineral soils, and old fields. In this classification, a table shows all indicator species and their prominence value classes in all VTs based on the equation:

$$\text{Prominence value} = \sqrt{\%\ \text{occurrence} \times \text{mean}\ \%\ \text{cover}}.$$

A **soil type** is a land unit type corresponding to a grouping of reasonably similar soils that have a certain productivity determined by site index (height in metres at 50 years) of dominant trees in natural stands. Soil types are identified according to mineral or organic composition, whether the land was ploughed in the past, drainage, depth to the compact layer, and lithology.

Each site region has its own **treatment unit type** (TUT) classification. There are between 8 and 15 TUTs in different classifications. Each TUT has several possible ST–VT combinations. Treatment unit types are identified on the grid with VTs and STs on different axes. It seems almost all combinations of VTs and STs are possible with few exceptions. Fact sheets in the classifications are given only for treatment unit types.

5.10.8 Newfoundland

5.10.8.1 Forest type classification in Newfoundland—The ELC regionalization for Newfoundland was completed by Dr. Damman, who generated an ecoregion map of the province (Damman 1983). He also developed an element-based ecosystem classification common to all 9 ecoregions of Newfoundland and 23 subregions. Thirty-three forest types are identified in this classification. This classification was further elaborated by Meades and Moores (1989) who included only merchantable forest types and nonforest vegetation occupying potentially merchantable sites. Nonforest vegetation types are included in this classification and available in several other publications (Northern Newfoundland, Damman 1963; Central Newfoundland, Damman 1964; Western Newfoundland, Damman 1967; and Eastern Newfoundland, Meades 1986, cited in Meades and Moores 1989). Thus, the basis of the forest type classification is a broader vegetation classification based on the Braun-Blanquet method. Associations (in the manual they are termed vegetation types) are defined by differential and dominant species. Site types (in the manual they are termed forest types) are defined by vegetation types and soil types. Forest types are grouped into six cover types including Balsam Fir Cover Type, Black Spruce Cover Type, Black Spruce Fen Cover Type, Kalmia–Black Spruce Cover Type, Hardwood Cover Type, and Hardwood Thickets and Hearth Cover Type. The soil classification is adopted from The System of Soil Classification for Canada (Canada Soil Survey Committee 1978). The subgroup level of this system is used to identify forest types along with differential species.

5.10.9 Yukon

5.10.9.1 Ecosystem classification in southeast Yukon—This classification is applicable to the southeast part of the Yukon (Logan Mountains and Liard Plateau). Its general design repeats that of the Manitoba classification (Zoladeski et al. 1995), but unlike the Manitoba classification all vegetation (not only forests) was included in this classification. It includes independent vegetation type subclassification and soil type subclassification. Management unit type subclassification is dependent because it represents a combination of vegetation and soil types. Seventy-seven vegetation types were distinguished.

5.11 Structural Analysis of FECs

In a typical classification (see Figure 6), the highest hierarchical level is a division, which divides the total classification area into several regions, and each element-based classification (lower levels) is applicable only for one region. Thus, in fact, each typical classification contains several uniform element-based classifications.

FECs are arranged on such principles in British Columbia, Alberta, New Brunswick, Quebec, and partly in Ontario. The regions in some cases are administrative units, while in other cases, they are units or combinations of units of the ELC or some other landscape division. For example, Saskatchewan has a common forest ecosite classification for parts of two ecoregions, including 34 ecological areas (ecodistricts?). In Ontario, element-based classifications are applicable to administrative units of the Ontario Ministry of Natural Resources. Table 4 compares the Canadian FECs.

In total in Canada there are more than 50 element-based forest ecosystem classifications applicable to separate land units. Unlike the US-NVC, most of these classifications identify their elements not only by features of the vegetation itself, but also by features of soil and physical environment in the identification process. To combine a future standard forest ecosystem classification and the proposed C-NVC, this apparent principal discrepancy should be eliminated. Forest ecosystem classifications in different provinces are not developed uniformly. Most of them are composite (multifactor) and consist of three related parts: vegetation classification, site classification, and soil ecological classification. Later we will call them subclassifications. Sometimes these subclassifications have independent keys and sometimes they are interlaced in a single key structure. On a very basic level one can distinguish several principal schemes for subordination of these subclassifications (see Figure 7). As we can see from these classification schemes, vegetation community type can be subordinated to ecosite type

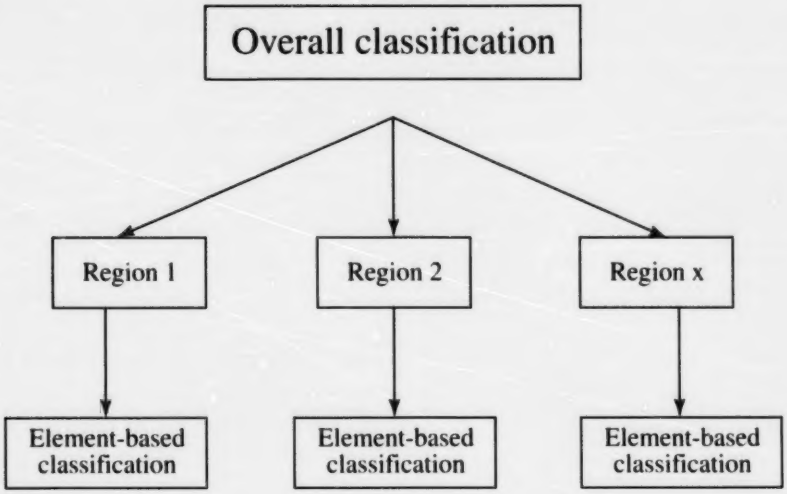

Figure 6. Typical arrangement of a Forest Ecosystem Classification.

(variant 5) or stay above it (variant 6). In all other cases, vegetation community type and ecosite type can be identified independently.

5.12 Classifications of the Canadian Conservation Data Centres

Conservation Data Centres (CDCs) have been established in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and Quebec. The most recent addition is the Atlantic Conservation Data Centre, which covers the four Atlantic provinces, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. The main tasks of CDCs are to collect, verify, organize, computerize, synthesize, and disseminate information on existing biodiversity and its changes as well as to rank elements of biodiversity in order to prioritize efforts to preserve biodiversity. Species of flora and fauna as well as natural communities represent the main elements of biodiversity. The term "Conservation Data Centre" is most commonly used for all of these provincial organizations, although it is not always part of the name (for example, Alberta Natural Heritage Information Centre). For uniformity, we will call all of them CDCs.

Most of the Canadian CDCs use the US-NVC (see section 4.7.2.1). They are the British Columbia CDC (British Columbia Conservation Data Centre 1996), the Alberta CDC (Corner et al. 1999), the Saskatchewan CDC (Belcher 1994), and the Manitoba CDC (Greenall 1996). The Ontario CDC has developed its own, quite elaborate classification for southern Ontario (Bakowsky 1996). The Atlantic CDC, which was established only recently, and the Quebec CDC have not yet developed ecological community classification systems.

5.12.1 Ontario CDC classification for Southern Ontario

This hierarchical system uses division at the highest hierarchical level and classification (element-based) at all lower levels (Bakowsky 1996; Lee et al. 1998).

Geographically this system is complementary to the forest ecosystem classifications of the Ontario Ministry of Natural Resources for other parts of Ontario described earlier (see section 5.10.5), but in terms of its concept and hierarchical structure it is a quite different classification. It applies to the southern region of the Ontario Ministry of Natural Resources. But unlike these forest classifications, the Ecological Land Classification for Southern Ontario (ELCSO) is much more elaborate both in terms of hierarchical scales and the scope of natural communities that are included.

The first hierarchical level is a division of the area of application into two site regions, which correspond to Hills's site regions 6E and 7E. At the second level, all natural communities are divided into three systems: Terrestrial, Aquatic, and Wetland Systems. The next two hierarchical levels, Community Class and Community Series, represent consequently more detailed subdivision of the systems. The next, or Ecosite level, is designed to correspond to the ecosite level of the ELC. Finally, the Vegetation Type level is designed to represent a close analog to the Ecoelement level in the ELC.

Thus, Vegetation Type is placed in a position subordinate to Ecosite Type. In this arrangement, each Ecosite Type must embrace several Vegetation Types, none of which can belong to another Ecosite Type. The classification includes 285 Vegetation Types including 54 Forest Vegetation Types. This is the most elaborate Canadian regional natural community classification discussed thus far.

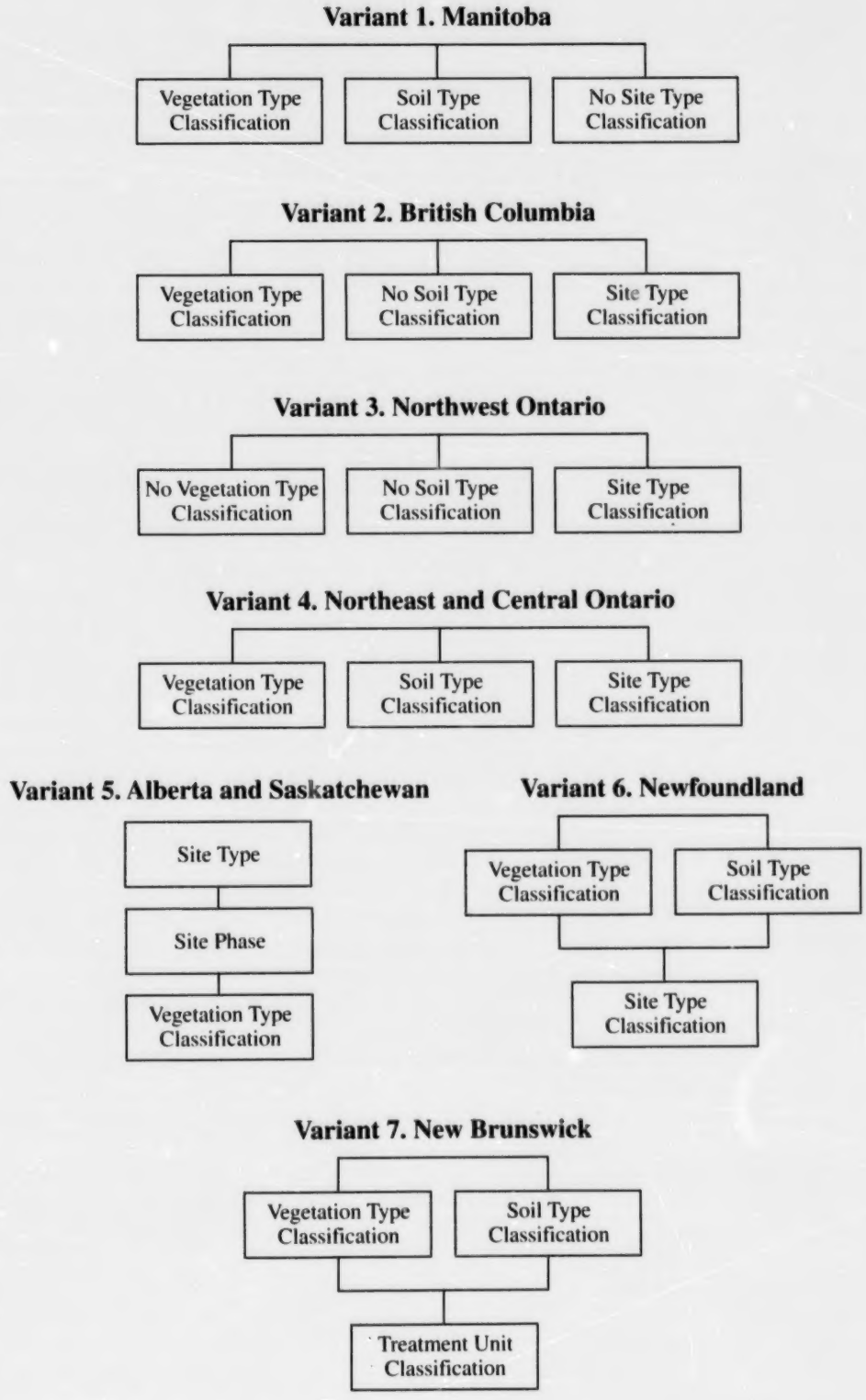

Figure 7. Arrangement of subclassifications in the Forest Ecological Classifications.

Table 4. Comparison of the Canadian Forest Ecosystem Classifications (FECs).

Classification	Classification(s) correspond to land units of which ecological land division?	Is veg. type independent of soil and site types or are they arranged hierarchically?	Is soil type independent of site and veg. types or are they arranged hierarchically?	Is site type independent of soil and veg. types or are they arranged hierarchically?	Does it have internal hierarchy?	No. of regions with separate site keys and veg. keys	No. of ecosites; veg. type and soil types	Forest ecosystems only?	Site defined by:
Biogeoclimatic Ecosystem Classification of British Columbia Ministry of Forests	Climate component classification of the BEC	Independent	Soil types are not defined	Independent	Yes	More than 20	Different in each biogeo-climatic unit	Some non-forested sites	Plant composition, parent materials, and landscape position
Ecosite classification of Alberta	Natural regions, parts of natural regions, or combination of natural regions, Alberta Natural Region Land Classification (Alberta Environmental Protection 1994)	Subordinated	Independent	Above vegetation types	3 levels: ecosite, ecosite phase, and plant community type	12	Different in each land unit	Some nonforested sites are identified	Dominant canopy trees and other indicator species
Ecosites of Mid-Boreal Ecoregions of Saskatchewan	Common classification for parts of two ecoregions, including 34 ecodistricts (the ELC)	Subordinated	Independent	Above vegetation types	3 levels: ecosite, ecosite phase, and plant community type	1	13 ecosites 23 ecosite phases 78 plant community types 17 soil types	Some nonforested sites are identified	Dominant canopy trees and other indicator species
Forest Ecosystem Classification for Manitoba	Common classification for parts of three forest regions of Canada (Rowe 1959)	Independent	Independent	Ecosites are not determined	No	1	33 vegetation community 22 soil types	Only forested land	Ecosites are not determined

(Continued)

Table 4. Comparison of the Canadian Forest Ecosystem Classifications (FECs). *(Continued)*

Classification	Classification(s) correspond to land units of which ecological land division?	Is veg. type independent of soil and site types or are they arranged hierarchically?	Is soil type independent of site and veg. types or are they arranged hierarchically?	Is site type independent of soil and veg. types or are they arranged hierarchically?	Does it have internal hierarchy?	No. of regions with separate site keys and veg. keys	No. of ecosites; veg. type and soil types	Forest ecosystems only?	Site defined by:
Forest Ecosystem Classification of Northwestern Ontario	Two administrative regions of the Ontario Ministry of Natural Resources	Independent	Independent	Ecosites are not determined	No	1	38 veg. types 22 soil types	Only forested land	Ecosites are not determined
Wetland Ecosystem Classification for Northwestern Ontario	Part of an administrative region of the Ontario Ministry of Natural Resources	Independent	Soil types are not determined	Ecosites are not determined	No	1	36 wetland types	Only wetlands	Ecosites are not determined
Terrestrial and Wetland Ecosites of Northwestern Ontario	Part of an administrative region of the Ontario Ministry of Natural Resources	Independent	Independent	Independent	No	1	56 site types 38 veg. types 22 soil types	All landscape. Only forested site and wetlands are described; some other sites named	Soil, canopy, and hydrological properties
Field guide to Forest Ecosystems of Northeastern Ontario	Administrative region of the Ontario Ministry of Natural Resources	Independent	Independent	Independent	No	1	22 site types 26 veg. types 23 soil types	Only forested land	Combination of soil features and indicator species
Forest Ecosystems of Central Ontario	Hills's landscape division (Hills 1961)	Independent	Independent	Independent	Site classification has two levels	1	25 site types 41 veg. types 26 soil types	Nonforested ecosites are listed but not described	Mainly by canopy species; subsites by soil water regime

(Continued)

Table 4. Comparison of the Canadian Forest Ecosystem Classifications (FECs). *(Concluded)*

Classification	Classification(s) correspond to land units of which ecological land division?	Is veg. type independent of soil and site types or are they arranged hierarchically?	Is soil type independent of site and veg. types or are they arranged hierarchically?	Is site type independent of soil and veg. types or are they arranged hierarchically?	Does it have internal hierarchy?	No. of regions with separate site keys and veg. keys	No. of ecosites; veg. type and soil types	Forest ecosystems only?	Site defined by:
Ecological land classification of the Ministère des Ressources naturelles du Québec	Province-wide hierarchical regionalization is a part of this classification	Independent	Independent, defined for some bioclimatic subdomains only	Site type (called ecological type) integrates potential vegetation and environmental features	9 regional-ization levels and 2 element-based levels	11 (at bioclimatic subdomains level)	190 ecosite overall (from 20 to 40 by bioclimatic subdomain); number of forest type and site type different for each bioclimatic subdomain	Some nonforested sites are identified	Potential vegetation (through indicator species groups) and environmental features (parent material texture, soil moisture class, and landscape position)
Forest Site Classification in Newfoundland	The classification is independent of the ELC (one for all areas of the province including 9 ecoregions)	Independent	Independent (System of Soil Classification for Canada, Canada Soil Survey Committee 1978)	No special site classification is developed	Veg. types classified on two levels	1	33 vegetation types	Forests, and having a potential for forestry	No special site classification is developed
Forest Site Classification in New Brunswick	Group of site regions	Independent	Independent	Instead of site class., treatment unit classification is developed (TUC); TUC depends on VC and SC	No	4	Different in each land unit	Only forests	Treatment unit is a combination of some vegeta-tion types with some soil types
Ecosystem Classification in the Southern Yukon	Portions of three ecozones (Ecological Stratification Working Group 1995)	Independent	Independent	No special site classification is developed	No	1	77 veg. types 29 soil types 18 Management Unit Types	All vegetation including forest, tundra, alpine, wetlands, etc.	

5.13 Classification Terminology in Canada

Many of the Canadian classifications do not have strictly defined names. It is therefore sometimes difficult to compare different classifications. A classification is a product that is proposed to potential users and thus should have a single name to distinguish it from other classifications.

6. Development of a Standard National Ecological Community Classification for Canada

6.1 Need for a Standard National Ecological Community Classification for Canada

The issues of biodiversity conservation and ecosystem management have become more important to Canadian society, and their implementation requires diverse scientific approaches and tools (Biodiversity Convention Office 1995). A standard national ecological community classification is an urgently needed tool to link local, provincial, and national levels. Such a classification could be used in the following areas:

Biodiversity conservation—A list and distribution of ecosystem types on different hierarchical levels could be used for the spatial and statistical analysis of current protected areas on different geographical scales (for example, determination of the number of ecosystems that have been protected) and planned protection activities. Such a tool is absolutely necessary to find gaps in the current protected areas network and to determine which ecosystems have been protected in several sites.

Ecosystem management—A classification could help to develop, analyze, monitor, and compare different ecosystem management techniques in different areas.

Environmental Assessment—A classification could provide a standard tool for land use projects that could affect natural resources, by allowing decision-makers to take into account not only species of interest but ecosystems as well. The conservation status of ecosystems should be ranked locally, regionally, nationally, and internationally.

We do not propose a particular name for such a classification, but in this publication we will use Canadian Classification of Ecological Communities (CCEC) and for the terrestrial portion of the CCEC, Canadian National Vegetation Classification (C-NVC). These terms will refer to a standard national classification, which we believe has to be developed as a collaborative effort. To maximize its usefulness, the CCEC must:

- be consistent throughout Canada and across North America;
- be applicable both on fine/local/field levels and on coarser levels including the countrywide level;
- be flexible enough to be applicable to all major types of natural communities (terrestrial, subterranean, riverine, lacustrine, estuarine, palustrine, and marine);
- have clear criteria for defining natural communities that are easy to identify in the field by trained ecologists;
- not have hypothetical components in the criteria;
- reflect recurring assemblages of biological species;
- be mappable at all levels (whether using remote sensing or ground surveys);
- be useful for collecting and storing spatial information on biodiversity distribution; and,
- have the potential to be merged with similar classifications in other countries in an eventual worldwide classification.

6.2 Proposed Structure of Canadian Classification of Ecological Communities (CCEC)

Our main objective is to make the proposed classification's framework broad enough to allow incorporation of all possible types of ecological communities, including ones that are not going to be classified in the near future. The highest hierarchical level of the CCEC is systems. This level has yet to be developed. Preliminarily it is divided into terrestrial, freshwater, marine, and subterranean systems.

Even though about 40% of Canada is covered by water (land 9.24 million km^2, freshwater 0.76 million km^2, and ocean 5.0 million km^2), the bulk of human activity and current interest is focused on the land area. We therefore suggest that at the first stage of developing a CCEC, the main effort should be to classify the terrestrial system. As we discussed earlier (see section 5.5), vegetation communities should be used to represent and classify biotic communities of the terrestrial system, although this will not be the case in some of the other systems (for example, subterranean).

The development of the CCEC will probably proceed over several decades. Nevertheless, we think it is important from the very beginning to design it in its entirety and fill in gaps afterward. Certainly the first system that should be developed is the terrestrial system. The overview and analysis of existing classifications in this paper have been undertaken with the intention of proposing a solution for developing only the terrestrial system of the CCEC. To avoid confusion with the fact that biotic communities in the terrestrial system are represented by vegetation communities, we suggest naming different components of the CCEC individually. For the terrestrial system a possible name is "Canadian National Vegetation Classification" (C-NVC).

The proposed structure of the CCEC is presented in Figure 8.

6.3 Aquatic Natural Communities and the CCEC

We recommend that aquatic ecosystems be separated from terrestrial ones at a very high hierarchical level. This would allow enough flexibility in the development of hierarchical structures of aquatic ecosystems. Traditionally they have only rarely been

Canadian Classification of Ecological Communities
Canadian National Vegetation Classification
Canadian Marine and Estuarine Ecological Community Classification
Canadian Forest Ecological Classification (vegetation component)
Others
Canadian Subterrestrial Ecological Community Classification
Canadian Freshwater Ecological Community Classification

Figure 8. Proposed structure of the Canadian Classification of Ecological Communities.

combined in any detailed ecosystem classification. The aquatic portion of the classification could be added by collaborative efforts between Canada and the United States. There are some aquatic ecosystem classification initiatives both in Canada (D.E. McAllister, 1999, "A model framework for a marine ecosystem classification for Canada's west coast," in preparation; Day and Roff 1999) and the United States (Holthus and Maragos 1995; Florida Natural Areas Inventory 1998) that can contribute to this development.

6.4 CCEC and Other Means of Representing Ecological Communities

We propose to develop a standard national ecological community classification. This classification would only be just a science-based conventional tool that would probably not fit every possible application, especially in science. Other methods of representing biotic communities will be equally legitimate.

6.5 How Can Element-based Classification (CCEC) and Regionalization (ELC) Complement Each Other?

The proposed CCEC is an element-based classification. There are several possible ways of combining it with the ELC, the regionalization type of classification. However, it is preferable to combine the two so that they would be completely compatible when applied to spatial biodiversity analysis and mapping projects.

Originally, the ELC was conceived as a mapping hierarchy, or a division from top to bottom: "Ecological land classification is a process of delineation and classifying ecologically distinctive areas of the Earth's surface. Each area can be viewed as a discrete system..." (Wiken 1986).

In the three upper levels of the hierarchy, each ecounit has its own unique name that reflects the fact that the ELC is a division and not a classical classification as defined earlier (see section 1). At the lower levels, especially at the ecosite and ecoelement levels, such a division approach is not feasible for most applications. It would produce millions of ecounits each having its own name, which would make it impossible to use them for communication purposes and analysis. In this case, it would serve only two purposes: (1) as an exact address of a land unit on the map, and (2) as a folder to collect information about this land unit. (Nevertheless, such a system can be used in computer GIS databases. Figure 9 illustrates such a scheme.) The lower levels of the ELC should probably be based on classical classification principles, that is, on the identification of recurrent elements of land pattern (see section 1.1).

The main question is how to make the intersection between division levels and classification levels. If we were to consider the ELC as a single hierarchical system, the most logical way to proceed would be to develop element-based classifications inside of each delineated land unit of the lowest division level. The resulting hierarchical scheme of the ELC could be as shown in Figure 10. Each unit of a higher hierarchical level completely embraces all units of the lower hierarchical level, which is normal for the structure of any hierarchy. In reality, for example, in the case of

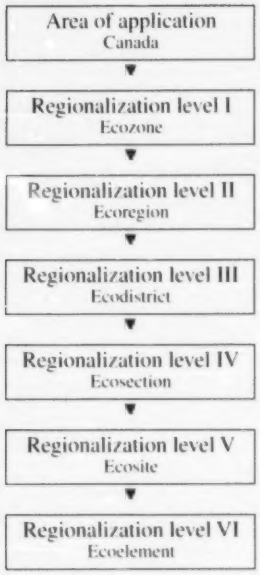

Figure 9. Hierarchy for the Ecological Land Classification using only regionalization at all levels.

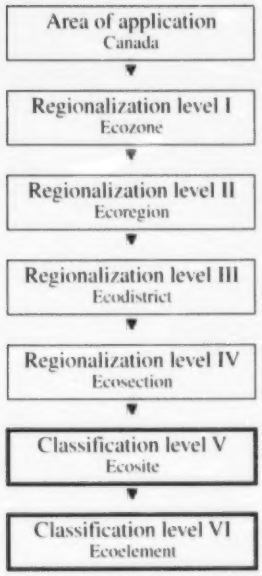

Figure 10. Common hierarchy for the Ecological Land Classification combining regionalization at the five higher levels with element-based classifications at the two lower levels.

Canadian forest ecological classifications, element-based classifications are developed not at the lowest division level land units ("cells"), but three hierarchical levels up. This kind of double hierarchical structure is shown in Figure 11. In fact even this kind of hierarchical arrangement does not reflect the present situation because land units, to which each of the forest ecological classifications is applicable, in most cases do not match the ELC land units. Instead of the ELC regionalization, they use other regionalization systems (see Table 4). "The ELC for Southern Ontario" classification is the same—it does not match the ELC hierarchy.

Thus, we presently have the following options for the development of the ELC:

1. Develop it further as pure regionalization, or a mapping hierarchy. As indicated earlier, this would result in millions of delineated land units, each with its own name. Such an arrangement is shown in Figure 9.

2. Develop it only to the ecosection level on regionalization principles and combine it with element-based classifications at lower levels. This combination can be done in several ways:

2.1 Develop element-based classifications in the "cells" (land units) of the lowest division level. In this case, we can have a single hierarchical scheme and the entire combination can be viewed as a single system combining division and classification principles. This arrangement is shown in Figure 10.

2.2 Develop element-based classifications in the "cells" of the higher division level. In this case, two hierarchies will overlap. This combination cannot be developed using a single hierarchical scheme, but it does not prevent the utilization of both the ELC and element-based classifications in a common analysis. This compatibility will enhance the analytical ability of both of them. This arrangement is shown in Figure 11.

2.3 Maintain the status quo. Areas of element-based classifications application do not match the land units of the ELC division. For some ecoregions, for example, there are two or more FECs and the same FEC can be applied for parts of more than one ecoregion. In this case, the ELC and element-based classifications are independent and cannot always be used in a common analysis (not completely compatible).

We believe that variant 2.2 is the best possible option. There could be several thematic element-based classifications, and biotic community classification is just one of them.

The next question is, in the "cells" (land units) of which ELC hierarchical level should the element-based natural community classification be developed? To date, there are more than 50 forest ecosystem classifications and natural community classifications applicable to separate land units. We believe that all of them should be united into a single system applicable to all of Canada.

Thus, this classification will be applicable to the same area as the ELC and consequently its elements and classes of higher hierarchical levels could be mapped in land units of all hierarchical levels of the ELC. This arrangement is shown in Figure 12. These two systems are completely compatible and could be used in a common analysis. In other words, we can quantitatively compare any two units of the ELC to conclude how different they are in terms of biotic community representation. For example, one

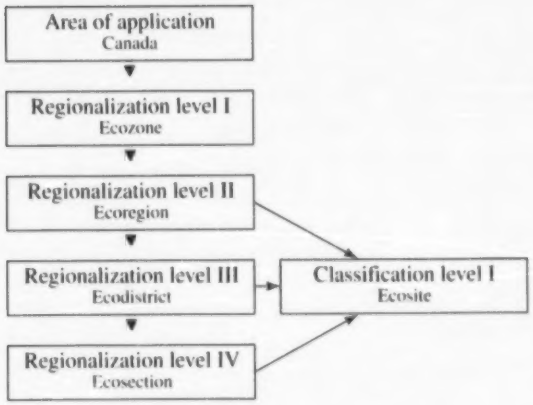

Figure 11. Double hierarchical scheme for the Ecological Land Classification and element-based classifications.

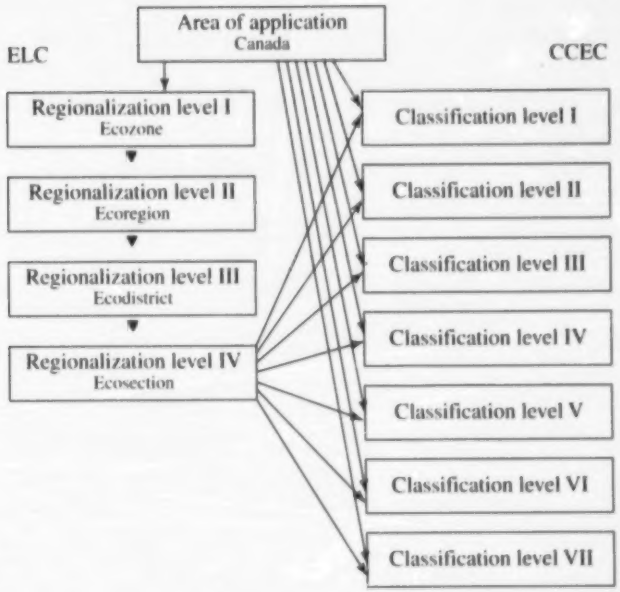

Figure 12. Proposed relationship between the Ecological Land Classification and the Canadian Classification of Ecological Communities.

ecodistrict (ecoregion, etc.) is composed of 60% VC-A (Vegetation Community A), 15% VC-D, and 25% of several other vegetation communities. Another ecodistrict (ecoregion, etc.) has 15% of VC-A, 45% of VC-D, and 40% of other vegetation communities (some of which may or may not be the same as "others" in the first ecodistrict). We can calculate a coefficient of similarity between these two ecodistricts. This also could give us an instrument to delineate two mapping units: it could be done in such a way that the coefficient of similarity is lowest. The opposite task is to analyze the distribution of vegetation communities in the ELC land units. For example, VC-K can be met only in ecodistrict I, whereas VC-L can be met in 100 ecodistricts of several ecoregions. One important application of it is to analyze how different vegetation types are preserved in protected area networks of different levels.

In some existing composed classification systems, an element-based classification is combined with regionalization in exactly the way that we propose. The biogeoclimatic classification in British Columbia is an example of such a combination. The entire province is divided into biogeoclimatic zones, and a common vegetation classification is applied to all of them. Krajina (1969) stated that "These ...[vegetation type] units provide another type of scientific integration other than biogeoclimatic zones, regions and formations." Another example is a combination of the U.S. Forest Service Ecoregional Classification[4] (regionalization type of classification) (Bailey 1980, 1983) and the US-NVC classification (element-based classification) (see section 4.7.2.1). The U.S. Forest Service Ecoregional Classification used the US-NVC for the characterization of land units. Both were used in the ECOMAP project.[5] This example is analogous to the relationship between the ELC and the proposed biotic community classification.

[4] Bailey (1980, 1983) developed a national regionalization of ecosystem units for the U.S. Forest Service. This is a division that subdivides the land surface into hierarchical spatial units of four levels: domain, division, province, and section.
Regionalization on these four levels has been carried out based on variations of climate, physiography, landforms, soils, and potential natural vegetation. Each hierarchical level has its own "driving variable".
Domains correspond to areas having distinctly different climates on the subcontinental level. They correspond to the regional climatic types of Köppen (1931). Divisions also reflect differences in climate, but on a more detailed level. Provinces are parts of divisions having homogeneous climax vegetation types. Sections correspond generally to the potential natural vegetation types of Küchler (1964).

[5] As an extension of Bailey's system, an Ecological Classification and Mapping Task Team (ECOMAP) was formed in the U.S. Forest Service to develop a consistent approach to ecosystem classification and mapping at multiple geographical scales. A national hierarchical framework of ecological units was developed by the ECOMAP team with four new levels below Bailey's section level: subsection, land type association, land type, and land type phase (McNab and Avers 1994). ECOMAP uses a single factor approach on some levels, and a synthesis approach on others.
At the subregional scale, sections and subsections are characterized by a combination of climate, geomorphic processes, topography, and stratigraphy. These factors influence moisture availability and exposure to radiant solar energy, which in turn directly control hydrological function, soil-forming processes, and potential plant community distribution. The classification and descriptions have now been completed throughout the United States at the section level (McNab and Avers 1994).

The relationship between regionalization and element-based classifications is also discussed in section 1.3.

6.6 Terrestrial System of CCEC: Canadian National Vegetation Classification (C-NVC)

6.6.1 Options for development of Canadian National Vegetation Classification

In section 3.5 we described why vegetation communities should be chosen to identify terrestrial biotic communities. The necessity to combine the floristic and physiognomic approaches in one classification that would be applicable both locally and globally was discussed by Beard (1973). The floristic approach is suitable for local and regional vegetation classifications, whereas physiognomic classification is the only appropriate approach on global and, in some cases, continental scales. Combination of the two approaches would permit linking local and global classifications into one classification.

As we saw earlier (see section 5), there are several classifications that have been developed or used in Canada. We summarize those that use floristic and other vegetation information for their development:

- Local or provincial forest ecosystem classifications (see section 5.10). Currently, in total there are more than 50 FECs applicable to separate regions in Canada. These classifications are not designed uniformly and can not be merged easily. Even if they could be merged into a Canadian Forest Ecosystem Classification (Meades et al. 1998), a classification for other types of nonforested ecosystems would still be needed.
- Provincial vegetation community classifications developed by provincial Conservation Data Centres (CDCs) in collaboration with TNC. They are completely compatible with the US-NVC and among each other exist in British Columbia, Alberta, Saskatchewan, and Manitoba (see section 5.12). Because of their emphasis on biodiversity conservation, CDC classifications have the added strength that they are comprehensive for all terrestrial types. All these classifications use the ICEC model, which should be considered as a candidate for a Canadian National Vegetation Classification.
- The Ontario CDC classification of vegetation communities called the "Ecological Land Classification for Southern Ontario" (ELCSO) (see section 5.12.1). This is a hierarchical classification using floristic criteria at the lowest level and physiognomic and abiotic criteria at all higher levels except the highest one (level VI). Because the lower units are vegetation-based, and similar to those of the other provincial CDCs, this classification is fairly compatible with the US-NVC, though more standardization would be desirable.
- The first approximation of a Canadian Vegetation Classification (CVC) proposed by the National Vegetation Working Group (see section 5.4). As follows from its name, this classification was designed as a national vegetation classification and consequently is another candidate for developing a Canadian National Vegetation Classification.
- Several vegetation classifications in national parks, some provincial parks, and some other local areas (see sections 5.8 and 5.9). These classifications, while extremely useful to the parks, are not consistent among each other and they are applicable only to relatively small areas. Therefore none of them can be easily used as a model for a national classification.
- The Ecological Land Classification developed by the Canada Committee on Ecological Land Classification (Ecological Stratification Working Group 1993, 1995). This classification divides Canada into ecoprovinces and successively finer spatial units called ecoregions, ecodistricts, ecosections, etc. This classification provides an excellent tool for looking at ecogeographic patterns of vegetation. However, a truly national vegetation classification cannot easily be developed as lower levels of the ELC because similar vegetation communities occurring in different land units of the ELC (for example, in different ecoregions) are a priori named differently. This makes the task of identifying floristic units comparable to the association more difficult. A Canadian National Vegetation Classification could be created, however, if a lower vegetation layer were treated as nonnested; see, for example, the Southern Ontario CDC approach in Lee et al. (1998), the Saskatchewan approach in Beckingham et al. (1996b), and the Alberta approach in Beckingham and Archibald (1996). Variants of relationship between element-based classification and regionalization type classification are discussed in section 6.5.

Thus, of the many classifications reviewed in Canada, two candidate classifications appear to provide the most suitable models for the development of a Canadian National Vegetation Classification—the CVC and the ICEC model that was used to develop the US-NVC. Either of these could be used in conjunction with other ecological classifications that contain a clearly defined vegetation layer, such as the one in use for Southern Ontario (Lee et al. 1998). A comparison of the two systems follows.

6.6.2 Comparison of CVC and ICEC systems

The CVC and the ICEC systems do not have any major underlying contradictions: both presume that the upper levels must be based on a physiognomic approach, and the lower ones on a floristic approach. The two upper hierarchical levels in both systems are very similar, although the number of classes and their criteria do not match completely. The midphysiognomic levels in these systems (Levels III and IV in the CVC and Group and Subgroup in the ICEC; see Table 5) use different criteria for their identification. In the CVC they are strictly quantitative and formal (based on canopy height and spatial cover), whereas in the ICEC they are based on physiognomic features that often directly or indirectly reflect environmental factors, climate, human impact, relative landscape position, and hydrology. A problem with the CVC is that floristically similar communities can still be allocated

to different classes in Levels III and IV. For example, trembling aspen forest can belong to the classes Very Tall, Tall, Intermediate, and Low at Level IV, which could greatly complicate the development of floristic units.

The ICEC's midhierarchical levels, being more flexible, have the advantage that they can potentially incorporate data from other physiognomic classifications much more easily. For Canada this will be especially important for incorporating the Canadian Wetland Classification System (CWCS), forest ecosystem classifications, and local names of ecosystem types. In addition, the subgroup level of the ICEC divides vegetation communities into natural/seminatural vs. cultural. This is very important for many practical issues, especially for biodiversity conservation. The CVC does not include this division.

The arrangements of the lower floristic levels are very similar in the two classifications, although the CVC has an intermediate level (VI) between the association level and the alliance level of the ICEC. This was likely designed to have a better correspondence with dominance-types (Whittaker 1962). The ICEC's two floristic levels are broadly compatible with other floristic systems, such as the Braun-Blanquet system, in that they rely on a combination of diagnostic species, including dominant species. An intermediate level based on dominance-types may be an unnecessary complication.

Whereas the CVC is essentially a hypothetical structure that has not been implemented, the ICEC system is widely implemented in the United States and elsewhere, including parts of Canada, and has support from state, federal, private, and professional organizations in the United States. Collaborations have been formed in Canada, and it is anticipated that the ICEC system could form the basis for a North American-wide approach to the classification of terrestrial vegetation.

A comparison of hierarchical levels of the CVC and the ICEC systems is presented in Table 5.

6.6.3 Comparison of ICEC system with provincial forest ecological classifications

As was mentioned earlier, there are more than 50 FECs applicable to various regions in Canada. All these classifications use vegetation, soil, and site features to identify their vegetation, soil, and site units. Some of them use additional groupings, namely treatment units. Nevertheless, all of them can be grouped into seven major groups/models according to how vegetation, soil, site, and treatment units relate to each other. One model, as used in the Manitoba FEC (Zoladeski et al. 1995) and in the Northwestern Ontario FEC (Sims et al. 1989), proposes the development of four subclassifications in which vegetation, soil, and site units can be identified independently from each other. Treatment units are identified as management-oriented groupings of vegetation, soil, and site units. The ICEC system can be used as a vegetation component in this kind of FEC.

Table 5. Comparison of the hierarchical levels of the CVC and ICEC systems.

CVC	ICEC	Comments
	Physiognomic levels	
Level I. Growth form and structure of vegetation	**Class.** Growth form and structure of vegetation	Quantitative parameters and number of classes are different
Level II. Growth form characteristics, e.g. leaf phenology	**Subclass.** Growth form characteristics, e.g. leaf phenology	Quantitative parameters and number of classes are different
Level III. Closeness grade of the uppermost stratum	**Group.** Leaf types, corresponding to climate	Criteria are different
	Subgroup. Relative human impact (natural/seminatural or cultural)	The subgroup level is absent in the CVC
Level IV. Grades on the basis of the uppermost stratum height	**Formation.** Additional physiognomic and environmental factors, including hydrology	Criteria are different
	Floristic levels	
Level V. Dominant /diagnostic species of uppermost or dominant stratum	**Alliance.** Diagnostic/ dominant species of uppermost or dominant stratum	This level is undeveloped in the CVC; it is widely developed in the U.S. portion of the ICEC
Level VI. Additional dominant species or life form from understory		This level is undeveloped in the CVC; it does not exist in the ICEC.
Level VII. Additional diagnostic species from any strata	**Association.** Additional diagnostic/ dominant species in any strata	This level is undeveloped in the CVC; it is widely developed in the U.S. portion of the ICEC

The most elaborate FEC in Canada is the British Columbia Biogeoclimatic Classification. It consists of four independent subclassifications: climate, vegetation, site, and seral. The vegetation subclassification consists of four hierarchical levels and is based on the Braun-Blanquet approach (that is, all four levels are defined by floristic criteria). We believe that the lowest level of this classification can be merged easily with the ICEC system because both of them use the same approach for this level. The vegetation types of other FECs in Canada are generally based on floristics, although the methods for identification of these types are not consistent among them. Merging them into a single consistent system compatible with the ICEC system requires crosswalking (translation between systems).

6.6.4 Canadian Wetland Classification and ICEC system

The Canadian Wetland Classification System (CWCS) is a very well designed physiognomic classification. It cannot be incorporated as a whole into the ICEC model because the principles of the upper hierarchical levels are based on different criteria. The lowest level of the CWCS, namely wetland types, can be partially used at the formation level with further floristic subdivision. We must make these two classifications as convertible as possible. In this case, it will lead to common lower four levels for both classifications and a double hierarchy at the higher levels, each branch of the double hierarchy representing correspondingly the CWCS and the C-NVC.

The Wetland Ecosystem Classification for Northwestern Ontario would be much easier to make convertible with the ICEC system because it is based mainly on vegetation criteria.

We believe that the wetland ecosystem classification could consist of two independent subclassifications: a vegetation community classification (which should be a part of the ICEC model) and an ecosite classification (reflect ecological processes and abiotic parameters of biogeocoenoses).

6.6.5 National park classifications and local vegetation mapping projects and ICEC system

Many local inventories and mapping projects (see sections 5.8 and 5.9) have been carried out in Canadian national parks. Vegetation types in these projects are based on physiognomy with some floristic features (in most cases when Landsat images were used) or on the Braun-Blanquet method. Both cases have a high probability of being linked with one of the three lowest levels of the proposed national classification. Of course, each project (or group of uniform projects) should be considered separately.

6.7 Conclusion: Proposal to Use ICEC System as Basis for Developing Canadian National Vegetation Classification

For the following reasons, we believe that the best way to develop a Canadian National Vegetation Classification is to make it highly compatible with the ICEC terrestrial vegetation classification system presented previously:

1. The ICEC system is the most widely encompassing ecosystem classification in North America (and in the world) in terms of both geographic area and ecosystem types. It is based on a very similar approach to that of the CVC, but unlike the CVC it is well developed at all the hierarchical levels. As developed in the United States, the ICEC includes more than 4700 natural communities at the lowest level. It is currently being applied in the United States, significant parts of Canada and Mexico, and some Caribbean and Latin American countries.

2. Such a system would be applicable to all terrestrial ecosystems, from tropical rainforests to deserts, and has the potential to include new, currently undefined, terrestrial ecosystems.

3. The system is already being used by provincial Conservation Data Centres in British Columbia, Alberta, Saskatchewan, and Manitoba. The association level, which is best developed in the United States, has been crosswalked to all Ontario FEC and Southern Ontario ELC classifications. These Conservation Data Centres have ecology staff who are able to coordinate classification development and review; furthermore, they are dedicated to a comprehensive assessment of all vegetation, not just forests, grasslands, or other subsets.

4. The ICEC system will be used as a component of a Canadian FEC currently being developed by the Canadian Forest Service in conjunction with provincial forest ministries.

5. The lower floristic levels of the ICEC are likely to be broadly compatible with other systems already used in Canada.

6. The US-NVC portion of the ICEC has received wide recognition in the United States, and "will now be the standard vegetation classification system for use by U.S. federal agencies and their cooperators" (Lund 1997). Fourteen U.S. federal government agencies have adopted the US-NVC as the national standard. These include the Forest Service, National Marine Fisheries Service, Fish and Wildlife Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, U.S. Geological Survey, and Environmental Protection Agency (FGDC 1997).

7. The development of the system "was closely coordinated with the development of the FAO [United Nations Food and Agriculture Organization] Land Cover Classification System to provide international links and to work towards the development of a truly global vegetation and land cover classification system" (Lund 1997).

We believe that making the Canadian national vegetation classification compatible with the ICEC would not only greatly facilitate the development of a national classification, but in conjunction with the US-NVC would also create the largest fine-scale classification entity in the world, both in terms of geographic area and diversity of ecosystems. This collaboration would make the eventual development of a hemispheric and world ecological com-

munity classification much easier. The European Vegetation Survey (Mucina et al. 1993; Rodwell et al. 1995) could be another major partner in this process. The lowest level is similar in both European and ICEC initiatives, whereas the higher levels are different. However, this difference is not a serious obstacle to comparing and eventually merging the two.

Although no single hierarchical level will be satisfactory to all users, and indeed alternative hierarchies (such as those based on ecological processes) may be recommended depending on the applications, the ability to work with a consistent standard for organizing ecological community information will enable Canadians to more effectively conserve and manage the great diversity of ecological systems present in the country.

6.8 Mapping Projects and C-NVC

Mapping projects will be one of the most important "consumers" of the C-NVC. Therefore all classes of all hierarchical levels must be made mappable. The classes of the classification should include any kind of land surface (including nonvegetated) to cover 100% of any terrestrial area. A legend for each classification project must be developed separately in accordance with the project goals, scale, and mapping area (see also section 1.5).

While upper hierarchical levels (I to V and partly VI) can be mapped using remote techniques, lower hierarchical levels (VI and VII) need ground surveys because they need floristic information not always discernable from a distance. Nevertheless, all levels of the proposed ICEC model are mappable. Practically, the ICEC system has already been applied in Waterton National Park in Alberta, Canada, which is congruent with Glacier National Park in Montana, United States. Both parks map their vegetation at the association level (lowest level) of the US-NVC (P. Achuff, personal communication).

6.9 Data Considerations

First, we propose developing the terrestrial system of the CCEC. The Nature Conservancy (TNC), in partnership with the network of Heritage Programs and Conservation Data Centres, has accumulated considerable experience during the last decade in developing and implementing the US-NVC. The fruit of this experience should be examined during the development of the implementation strategy for the C-NVC.

The development of the classification should start by closely reviewing existing local classifications, their elements, and plot descriptions ("relevés"). Three databases have to be created:

Classification database—This database should include complete descriptions of all classification elements as well as descriptions of classes of higher hierarchical levels and complete sets of identification criteria. This database must be regularly updated to include new classification elements and amendments.

National plot description database—An important relationship exists between the inventory methods and classification in that a standard classification requires a standard plot description method. We propose to develop plot description template(s) in a way that would provide information not only to characterize the floristics of the given locality, but optionally also the edatope and the site including characterization of ecological processes and disturbance regimes. This would allow for a wider use of the plot description databank. For such areas of human activity as forestry, ecosystem restoration, natural rangeland management, and prediction of ecosystem successions, abiotic characteristics of the site are equally important to the floristics. The same plot description database could be used to develop the standard vegetation unit types descriptions and to characterize abiotic parameters and ecological processes of corresponding biogeocoenoses. In this case, standard characterization of associations in the vegetation classification could be elaborated by probable variants of edatope and site parameters. Likewise, elementary site and edatope types could be characterized by a range of corresponding vegetation communities. This is the exact method that was used in some forest ecosystem classifications in Canada, for example, in a site classification for Northwestern Ontario (Racey et al. 1996). Each site type is characterized by a range of corresponding edatope types (soil types) and vegetation community types.

Today many provincial agencies and organizations have their own local databases of vegetation cover sample descriptions. The main keepers of these data are the Conservation Data Centres and the forest ministries. A single system of collecting, recording, and storing descriptions of biotic community samples must be set up. A standardized plot description template(s) along with instructions on how to fill it out must be developed. An example of a standard plot description template was proposed by the National Vegetation Working Group (1990), whereas the Conservation Data Centres use the template and instructions developed by The Nature Conservancy and widely applied and perfected over more than 20 years in the western hemisphere. We believe that these two templates and their associated instructions should be considered in developing the template to be used in a C-NVC. A national plot description database should include examples of all classification elements over the entire range of their occurrence. It will take probably several decades to have satisfactory representation for all classification elements.

Names database—Because classification will be developed over an extended period of time, a system to track changes should be established. A system similar to that used to name software versions could be used.

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